

**FINAL
SUMMARY OF PROPOSED WORK FOR
TECHNOLOGY APPLICATION OF LOW COST
EMPLACEMENT OF SLOWLY-SOLUBLE ORGANIC
SUBSTRATE FOR ENHANCED *IN SITU* REDUCTIVE
DECHLORINATION OF HALOGENATED
ALIPHATIC HYDROCARBONS
ARNOLD AIR FORCE BASE, TENNESSEE**



U.S. AIR FORCE



NOVEMBER 2003

Prepared for the

**Air Force Center for Environmental Excellence
Brooks City-Base, Texas**

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LIST OF ABBREVIATIONS USED IN THIS DOCUMENT

1. 1TCA – 1,1,1-Trichloroethane
2. 2TCA – 1,1,2-Trichloroethane
3. 1DCA – 1,1-Dichloroethane
4. 2DCA – 1,2-Dichloroethane
5. 1DCE – 1,1-Dichloroethene
6. AIAFB – Altus Air Force Base
7. ArAFB – Arnold Air Force Base
8. AAPT – Accelerated Anaerobic Pilot Test
9. AFCEE – Air Force Center for Environmental Excellence
10. BTEX – Benzene, Toluene, Ethylbenzene and Xylenes
11. CA - Chloroethane
12. CAH – Chlorinated Aliphatic Hydrocarbons
13. cDCE – *cis* 1,2-dichloroethene (*cis*-1,2-dichloroethylene)
14. COC - Chain of Custody (refers to records)
15. COR – Contracting Officer’s Representative
16. DOC - Dissolved Organic Carbon
17. DO - Dissolved Oxygen
18. DAFB – Dover Air Force Base
19. DDHU – Defense Depot Hill Utah
20. DNAPL – Dense Non Aqueous Phase Liquid
21. EAFB – Edwards Air Force Base
22. EISOPQAM - Environmental Investigation Standard Operating Procedure and Quality Assurance Manual
23. HLB – Hydrophilic/Lipophilic Balance
24. HRC® – Hydrogen Release Compound
25. IDW – Investigative-Derived Waste
26. LNAPL – Light Non-Aqueous Phase Liquid
27. MCL – Maximum Contamination Limits
28. MSDS – Material Safety Data Sheet
29. MSL – Mean Sea Level
30. OC – On Center
31. O&M – Operation and Maintenance
32. ORP – Oxidation-Reduction Potential
33. OU - Operable Unit
34. PCE – Tetrachloroethene (Tetrachloroethylene)
35. PID – Photoionization Detector
36. POL – Petroleum Oil Lubricants
37. PPE – Personal Protective Equipment
38. PRBB – Permeable Reactive Biobarrier
39. PSI – Pounds Per Square Inch

- 40. PVC – Polyvinyl Chloride
- 41. SU – Standard Units
- 42. TCE – Trichloroethene (Trichloroethylene)
- 43. TOC – Total Organic Carbon
- 44. TSI – Terra Systems Inc.
- 45. VC – Vinyl Chloride
- 46. VOC – Volatile Organic Compound

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1.0 INTRODUCTION

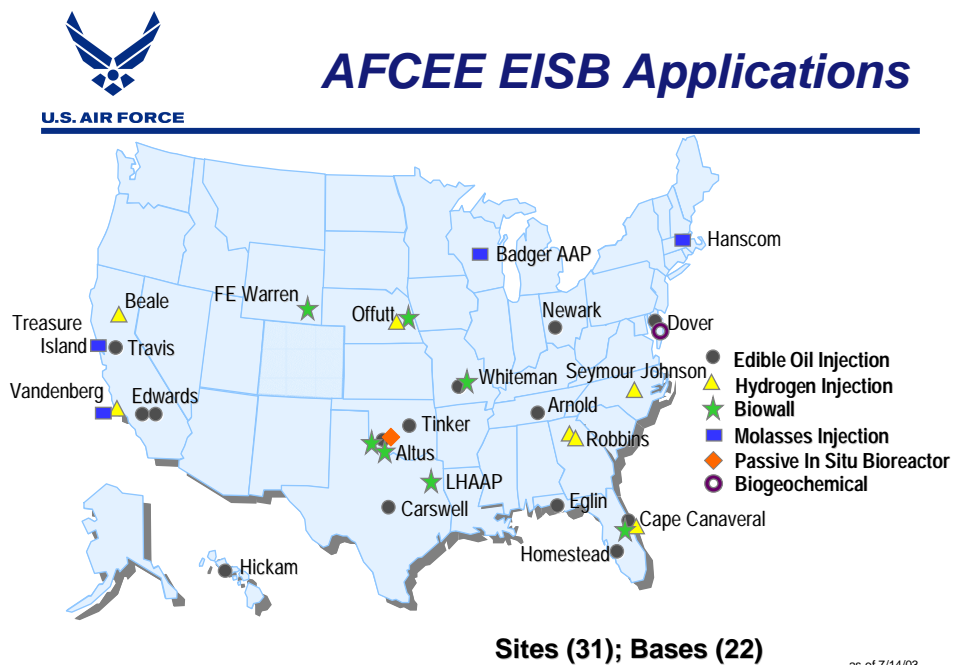
The presence of chlorinated solvents in groundwater is a frequently encountered problem associated with the use of many products containing these chemicals for many common applications. These include dry cleaning, metals parts finishing and cleaning, and painting operations (US EPA 1996a). Incidental releases or disposal of these materials over time from large-scale operations such as storage tanks or from relatively small applications such as textile spot cleaners or metal-shop parts cleaners have resulted in this wide-spread groundwater problem. Research into methods of remediating these situations is ongoing. Initially chlorinated solvents were considered to be mostly recalcitrant in the environment and only by physical or chemical means could they be removed. However, more recent work has shown that these compounds can be degraded biologically under favorable environmental conditions.

One of the most efficient biological pathways for the degradation of chlorinated solvents is anaerobic reductive dechlorination. In the environment, the process is slow, generally hindered by inappropriate site geochemistry and biologically unfavorable conditions. However, recent evidence has shown that the introduction of readily degradable substrates such as sugars and oils can alter the conditions of the subsurface and promote the degradation of the chlorinated solvents (Lee et al. 1998). The objective of the project at Arnold Air Force Base (ArAFB) that is described in this Work Plan is to develop and demonstrate a process for distributing an organic amendment into a contaminated aquifer for the purpose of enhancing *in situ* reductive dehalogenation of chlorinated solvents in groundwater. The project is being performed as part of the Enhanced Bioremediation of Chlorinated Solvents Initiative of the AFCEE Technology Transfer Program. The work will be performed in accordance with the *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water* (US EPA 1998) and the *Statement of Work for Technology Application of Low Cost Emplacement of Organic Substrate for Enhanced In Situ Bioremediation of Halogenated Aliphatic Hydrocarbons* prepared by AFCEE/ERT (1998). The basis for this demonstration and prior work related to this approach are described in the following section.

1.1 BACKGROUND OF THE TECHNOLOGY

The *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water* (US EPA, 1998) outlines methods to quantify chlorinated solvent destruction *in situ*. In addition, this protocol describes the biogeochemical conditions under which the destruction of chlorinated solvents occurs. The established conditions under which chlorinated solvents are subject to destruction are termed Type 1 or 2 conditions. Type 1 conditions are primarily established by the presence of an anthropogenic source of organic carbon (e.g. fuel spills, landfill leachate, etc.). Type 2 conditions are primarily established by the presence of a naturally-occurring source of organic carbon. Organic carbon can act as an energy source (*i.e.*, electron donor) for subsurface microbes. This biodegradation of this organic carbon results in the establishment of reducing conditions and creates a demand for electron acceptors. Chlorinated solvents (e.g., tetrachloroethene, trichloroethene, etc) are highly oxidized compounds and can be used by microbes as electron acceptors under Type 1 or 2 anaerobic conditions.

The AFCEE Technology Transfer Program is a field-based testing program for innovative site characterization and remediation technologies. The AFCEE Technology Transfer Program includes an Enhanced Bioremediation of Chlorinated Solvents Initiative. This project and similar projects are being executed at numerous sites to independently evaluate the applicability, cost, and performance of enhanced bioremediation technologies under a wide variety of site conditions. As the time of preparation of this work plan the AFCEE Enhanced Bioremediation of Chlorinated Solvents Initiative includes the following sites and technologies:



The enhanced bioremediation approach proposed in this workplan is based upon the injection of edible oil to provide a source of dissolved organic carbon to promote chlorinated solvent treatment via reductive dechlorination and sequestration. Edible oils have been selected as an organic substrate because their physical characteristics which allow them to act as longer-term, slow release substrates and to promote the sequestration of the contaminants in the biological reactive treatment zone.

Edible oil injection provides microorganisms with a biodegradable food source (i.e., an electron donor organic substrate) by creating subsurface conditions favorable for dehalorespiring microorganisms to perform anaerobic conversion of chlorinated ethenes such as tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (cDCE), trans-1,2-dichloroethene, and vinyl chloride (VC) and chlorinated ethanes including 1,1,1-trichloroethane (1TCA) and its daughter products 1,1-dichloroethane (1DCA), 1,1-dichloroethene (1DCE), and chloroethane (CA) to non-chlorinated end-products including ethene and ethane, respectively.

Experience gained during the Accelerated Anaerobic Pilot Test (AAPT) at Dover AFB, DE provided practical information regarding the inherent challenges of organic substrate distribution. In the AAPT, a readily biodegradable soluble organic substrate (i.e., lactate) was added by flushing dissolved substrate through the treatment zone using a series of injection and production wells (Lee et al. 1998). Although this closed-loop approach was effective, construction, operation and maintenance costs were relatively high. Treating biofouling that developed in wells and pumping equipment became a major cost burden. Conversely, at sites where “slowly-soluble” vegetable oil was introduced into the aquifer via one or more injection wells, long-term operation and maintenance (O&M) was minimal (Lee et al. 2001). To date, at pilot tests conducted at three AFBs previously as part of this effort under the AFCEE Enhanced Bioremediation of Chlorinated Solvents Initiative, the data have supported the longevity of both oil and oil emulsions in the aquifer without the need for replenishment or maintenance for greater than two years.

The use of slowly-soluble edible oils as a groundwater amendment reduces costs in three ways:

(1) The cost per pound of active ingredient in oil is approximately \$0.50 - \$0.70 per pound for oil compared to \$6.00 to \$12.00 per pound active ingredient for Hydrogen Release Compound (HRC[®]) (Harkness 2000). Soluble substrates are relatively inexpensive ranging from \$0.12 per pound for molasses, \$0.31 per pound for methanol, to \$1.15 sodium lactate (Raymond et al. in press). However because the efficiency of transformation of the substrate to hydrogen varies, the cost per pound of hydrogen generated ranges from \$1.64 for methanol, \$5.00 for vegetable oil, \$5.32 for molasses, \$32 for sodium lactate, to \$111 for HRC.

(2) The oil has the ability to slowly dissolve into the aquifer providing a natural time-release mechanism, similar to HRC[®]. Laboratory studies in anaerobic microcosms have shown that oil remains biologically available for greater than two years (personal communication with R. C. Borden). The final longevity of edible oils in the environment remains untested although estimates range from three to five years, depending on the amount of oil introduced and the concentrations of electron acceptors (O₂, NO₃, SO₄) already in the aquifer. However, the technology offers the potential that only a one-time oil application would be needed to treat a contaminated aquifer. A one-time application of edible oil is advantageous compared to HRC[®], which typically requires multiple re-injections to maintain the desired biological activity. This approach also greatly reduces costs by eliminating recirculation pumps and wells and additional operation and maintenance (O&M) associated with the injection of soluble, readily biodegradable substrates as a result of biofouling.

(3) Edible oils are consumed more slowly by microorganisms yielding electrons on an as needed basis, with less opportunity to “waste” substrate as methane via methanogenesis.

Soybean oil is one of the least expensive edible oils and is widely available throughout the United States. However, it is relatively viscous and is not easily distributed from the point of injection. Preparation of an emulsion of soybean oil, water, and a surfactant will allow for a wider distribution of the oil. In contact with soil particles, the emulsion will break and the oil droplets will coalesce onto the soil particles thereby providing a long lasting carbon source to support reductive dechlorination.

As part of the AFCEE Enhanced Bioremediation of Chlorinated Solvents Initiative, injections at three of four Air Force bases have been completed. For the purpose of the pilot test demonstrations at these bases, soybean oil was introduced to create a permeable reactive biobarrier (PRBB) with closely spaced monitoring points on either side of the barrier. This configuration allows for evaluating both the distribution of the oil into the aquifer and the effectiveness of the oil for stimulating *in situ* reductive dechlorination.

In the Fall of 1999 at Dover AFB, Delaware, two different PRBB designs for distributing the soybean oil were installed: 1) injection of closely spaced “plugs” of soybean oil via temporary well points installed on 2-foot centers and 2) injection of a soybean oil-water mixture, emulsified with a food-grade surfactant (the soybean oil emulsion), via temporary well points installed on 5-foot centers. Both the soybean oil and soybean oil emulsion were followed by a pulse of water to help distribute the substrate into the aquifer and to entrain the oil droplets throughout the contaminated groundwater zone between 10 and 30 ft below ground surface (bgs). All the injection points were installed with a Geoprobe[®] apparatus. The radius of distribution achieved around each barrier and the effect on the hydraulic conductivity of the aquifer both at the point of injection and downgradient are being monitored. The chemical/biological factors being evaluated include the biodegradation of the parent contaminants, formation of metabolic daughter products, the biotransformations of electron acceptors, including nitrate, sulfate, and iron (III), and the formation of reducing conditions in the aquifer as measured by pH, dissolved oxygen and oxidation-reduction potential in groundwater.

In many reductive dechlorination situations, the biodegradation of more highly chlorinated parent molecules such as PCE and TCE has been observed to stop at cDCE. This occurred at the AAPT at Dover AFB. To overcome this limitation, a known TCE-degrading microbial culture was grown and introduced into the test plot. Within three months the cDCE had been converted to VC and ethene.

There are two areas of the chlorinated solvent plume at Dover AFB – an anaerobic zone where limited transformation of PCE and TCE to cDCE and VC occurs and an aerobic downgradient zone where cDCE and VC are degraded. However, any PCE and TCE that reach the aerobic zone are not degraded. Because the disappearance of PCE and TCE is of paramount importance to DAFB and the PRBBs have been shown to effectively produce conditions capable of enhancing the reductive dechlorination of TCE to cDCE, additional soybean oil emulsion was injected at DAFB to evaluate the ability of the barrier to promote dechlorination of PCE and TCE .

In the summer of 2000 at Edwards AFB, California, a PRBB composed of four injection points was installed 45 to 60 feet below surface into the TCE-contaminated aquifer. The substrate used was a soybean oil emulsion prepared by mixing food-grade lecithin emulsifier with soybean oil and groundwater from the site. The radius of influence away from each injection point, the impact over time on the enhancement of anaerobic conditions and promotion of reductive dechlorination of the TCE, and the changes in subsurface permeability have been measured periodically since installation. Rapid removal of TCE was observed in both injection and monitor wells impacted by the emulsion. The results suggested both sequestration and possible biodegradation of TCE. However, no daughter or end-products were measured to confirm that biodegradation had occurred. There was also circumstantial evidence that use of lecithin as the emulsifier promoted excessive methane production, subsurface biofouling and reduced permeability.

In the fall of 2001, a PRBB comprised of six injection points was installed 8 to 18 ft below surface into the TCE-contaminated aquifer in the SS-17 plume at Altus AFB, Oklahoma. A second, smaller pilot was also conducted in the OU-1 plume at Altus AFB. Soybean oil emulsion containing food grade commercial emulsifiers and a small amount of lactate were injected at each pilot. The injection and monitor wells have been monitored periodically for over one year. High levels of sulfate (up to 2,000 mg/L) were consumed and biodegradation of TCE to VC and ethene was promoted. Sulfate levels above 100 mg/L exert a high demand for substrate. There was also some evidence of abiotic transformation of TCE at the smaller OU-1 former landfill test site.

Solid Waste Management Unit 10 (SWMU 10) at Arnold AFB is the fourth test site to be completed under the AFCEE Enhanced Bioremediation of Chlorinated Solvents Initiative. SWMU 10 was chosen because of the interest in applying this bioremediation technology at a site containing dense non-aqueous phase liquid (DNAPL) and at high concentrations. Reduced degradation products including vinyl chloride and chloroethane have been detected in the groundwater suggesting that a microbial population capable of complete dechlorination is present at the site.

1.2 OBJECTIVES OF PILOT TESTS AT ARNOLD AIR FORCE BASE

The following objectives are planned for the Arnold Air Force Base pilot tests:

- Test the applicability of the edible oil to sequester, immobilize, and reduce the mass flux of contaminant release from a dense non-aqueous phase liquid (DNAPL)
- Evaluate the potential for the edible oil and edible oil emulsion to promote the biodegradation of high concentrations of chlorinated solvents

2.0 PROJECT SCOPE AND SCHEDULE

2.1 SITE DATA REVIEW

2.1.1 Information Sources

Initial data from Arnold Air Force Base (ArAFB) were received in January to June 2003. The information was reviewed to familiarize project designers with the site and to identify potential locations to install the edible oil pilot tests. The site under consideration was identified as the source area of Solid Waste Management Unit 10 (SWMU-10). A base location map is provided as Figure 2-1. The following documents were provided by ArAFB personnel to provide general site information:

- CH2MHill 1999. SWMU 10 DNAPL Delineation. Prepared for Arnold Air Force Base. Draft Final. March 1999.
- Arnold Engineering Development Center 2000. Installation Restoration Program. FY 2000. Solid Waste Management Unit 10 Report for Interim Groundwater Monitoring, Groundwater Treatment, and Solvent Recovery System, Arnold Air Force Base, Tennessee. Draft June 30, 2000.
- ACS 2001. FY 2000-2001. Solid Waste Management Unit 10 Annual Interim Measure Operation and Effectiveness Monitoring Report for Arnold Air Force Base, Tennessee. Draft June 2001.
- ACS 2002. FY 2002. Solid Waste Management Unit (SWMU) 10 Site WP-8 Leach Pit No. 1, Annual Interim Measure Operation and Effectiveness Monitoring Report for Arnold Air Force Base, Tennessee. Draft July 2002.

2.1.2 Site Setting

Arnold AFB is located between the cities of Tullahoma and Manchester, Tennessee in Coffee County (ACS 2001). It is bordered by Highway 55 on the northwest and US 24 on the northeast (Figure 2-1).

The site under consideration was identified as SWMU 10. The following information about this location was provided in CH2MHill (1999).

“SWMU 10 (Site 8) is located within the northern portion of the Main Test Area (MTA) of the Base, just north of the Model Shop Building. The site is the former location of the Vapor Degreaser Building and Leach Pit No. 1 (see figure 1). The Vapor Degreaser Building was in operation from the early 1960s through the early 1990s. The facility consisted of a stainless-steel vapor pit, approximately 15 feet deep, that was used to clean and degrease metal parts. PCE and 1,1,1-trichloroethane (1,1,1-TCA) were the primary chlorinated solvents used in the degreasing process. The degreasing facility also included a large concrete pad located outside of the building where larger pieces of metal were cleaned. The vapor degreasing facility was removed in the early 1990s.

“Spent solvents from the vapor degreaser were reportedly disposed of into Leach Pit No. 1, a 20-foot by 40-foot soil-lined pit filled with limestone rock. The pit was located east of the vapor degreaser building and was in operation from the 1950s to 1972. An estimated 31,000 gallons of chlorinated solvents and a variety of acids used during the metal-cleaning operations were discharged to this leach pit.

“An open channel flow discharge ditch reportedly bisected the site from northwest to southeast and eventually discharged into the western end of Ditch H (refer to figure 1). Chlorinated solvents likely entered the ditch as a result of metal-cleaning activities that occurred near the former ditch.

“In 1995, Arnold AFB excavated and treated contaminated soil in the immediate area of the former leach pit and discharge ditch. The primary objective of this remedial action was to treat the contaminated soil to reduce the volatile organic compound (VOC) contamination to levels below U.S. Environmental Protection Agency (EPA) and Tennessee Department of Environment and Conservation (TDEC) soil action levels (Arnold Engineering Development Center [AEDC], February 1996). Contaminated soil was excavated to the water table, a depth of roughly 16 feet bgs, over an area approximately 120 feet by 80 feet. This area primarily included the southern portion of the site located inside of the current security fence. The excavated soil was treated using a low-temperature thermal desorption (LTTD) process to remove the VOCs. The treated soil was then used to fill the onsite excavation.

“In March 1996, Arnold AFB installed a groundwater extraction and treatment unit (GWTU) within the source area. The original system consisted of four shallow aquifer extraction wells and a treatment unit designed to separate pure-phase VOCs from the groundwater and treat the separated groundwater by air stripping and carbon polishing. During installation of one of the extraction wells, DNAPL was encountered within the soil and groundwater below the backfill treated soil (16 feet bgs). The lateral and vertical extent of the DNAPL was unknown.

“The DNAPL was analyzed and determined to be greater than 90 percent PCE and 2.5 percent cutting oil. The reported properties of the DNAPL are:

- Density 1.63
- Viscosity 1.33
- Interfacial tension 18.16 dynes/centimeter (cm)”

2.2 SITE SELECTION AND CHARACTERIZATION

2.2.1 Site-Specific Geochemistry and Contaminant Information

Numerous wells and soil borings have been installed in this area of the site as part of previous efforts to characterize the site and determine the horizontal and vertical extent of contamination in groundwater. Volatile organic compounds (VOC) detected in April and October 2002 are shown in Figure 2-2. Primary contaminants ($>1,000 \mu\text{g/L}$) in the source wells 170 and 415 in 2001 included PCE, 1TCA, and 1DCE. Compounds found at intermediate concentrations of 100 to $1,000 \mu\text{g/L}$ included acetone, 1DCA, 1,2-dichloroethane (2DCA), cDCE, methylene chloride, 1,1,1,2-tetrachloroethane, 1,1,2-trichloroethane (2TCA), TCE, and trichlorofluoromethane (TCFM). Compounds detected at below $100 \mu\text{g/L}$ included carbon tetrachloride, chlorobenzene, chloroethane, chloroform, 1,2-dichlorobenzene, tDCE, 1,2-dichloropropane, ethylbenzene, naphthalene, 1,1,2,2-tetrachloroethane, toluene, 1,1,2-trichloro-1,2,2-trifluoroethane, 1,2,4-trimethylbenzene, VC, and o,m,p-xylenes.

The relevant information was extracted from the reports that were provided and used to characterize the areas planned for performing the pilot tests. Information on selected wells included construction details and typical depth to water of monitoring wells in the area; geochemical and bio-indicator parameter

information from historical sampling and analysis events; and recent data on target chlorinated solvents in the groundwater. The information is summarized in the Tables 2-1, 2-2 and 2-3.

2.2.2 Site-Specific Groundwater Hydrogeology

A series of pumping tests were conducted in SWMU 10. Well 402 was pumped at the maximum yield (average flow of 0.73 gpm) for three days and allowed to recover for three days. The geology of the unit and the results of the pumping tests are described below (ACS 2002):

“The shallow aquifer in the source area can be divided into upper and lower parts given the presence of a silt/chert/sandstone zone at depths of 26 to 28 feet. This semi-confining zone separates two water-bearing sand zones. Saturated, fine sand having clayey silt and silt interbeds extends from approximately 16 to 26 feet below ground surface (bgs) and is overlain by clayey silt and fill material. The lower part of the shallow aquifer from approximately 28 to 39 feet bgs consists of fine silty sand and fine to medium sand. The sands are interbedded with thin sandstone lenses and silty clay. The lower part of the shallow aquifer is confined below by silty clay and clayey gravel.

“The Well No. 402 pumping test was considered useful for determining aquifer parameters for the lower part of the shallow aquifer since Well No. 402 fully screens the lower part of the aquifer. Well No. 402 also screens the upper part of the aquifer. However, the majority of water produced from Well No. 402 came from the lower part of the aquifer, evidenced by drawdown responses that occurred in nearby observation wells completed in only the upper part of the aquifer. These upper observation wells showed delayed and lesser amounts of drawdown when Well No. 402 was pumped than when extraction wells completed in the upper part of the aquifer were pumped individually.

“The screen of Well No. 402 fully penetrates the lower sands of the shallow aquifer. A confining layer exists at the base of the aquifer. A semi-confining silt/sandstone/chert zone separates the lower and upper sands. As a result of the semi-confining zone, pumping of the lower sands results in delayed response in the upper sands. Therefore, solutions for a leaky aquifer model were employed. Solution methods for confined and unconfined models were also employed for comparison.

“The corrected drawdown data for the stated observation wells were analyzed using the Hantush-Jacob (1955) and Hantush (1960) solution methods for a leaky aquifer...

“The Theis, Cooper-Jacob and Theis recovery confined solution methods were used for a confined aquifer model. The Theis and Cooper-Jacob unconfined solution methods were used for an unconfined aquifer model. Aqtesolv software was employed for the analyses.

Table 2-1. Construction Details for Existing Wells in Vicinity of Proposed Pilot

Well	Depth Code	Elevation TOC ft	Elevation GS ft	Casing Materials	Screen Begin Depth ft	Screen Length ft	Screen Slot Size	Seal End Depth ft	Depth ft	Casing Diameter in
MW-170	S	1081.59							35.0	0
MW-405	S	1085.34	1083	PVC	30	10	10	27	40.0	2
MW-406	S	1084.46	1082	PVC	19	20	10	17	39.0	2
MW-415	S	1081.17	1082	PVC	30	10	10	26	40.0	2
MW-421	I	1084.41	1082	SS	76	10	10	72	85.5	2
MW-452	I	1084.38	1083	SS	76	10	10	74	86.5	2
MW-520	D	1082.77	1083	PVC	94	26	10	90	119.5	2

D = Deep

SS = Stainless Steel

I = Intermediate

PVC = Polyvinyl Chloride

GS = Grade Surface

TOC = Top of Casing

S = Shallow

Table 2-2. Summary of Groundwater Geochemical and Bio-Indicator Parameter Data

MW	Date	Cond.	ORP	DO	pH	NH ₃ -N	Dis Fe ⁺²	NO ₃ -NO ₂ -N	SO ₄	Alkalinity	Chloride	TOC	Dis Mn
Identification	Sampled	mS/cm	mV	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
MW-170	10/23/01 1/29/98	213	152	0.33	5.1	<0.2	11.2	0.11	<2	<3	110	9.0	0.064
MW-405	10/23/01	272	149	0.11	5.0								
MW-406	10/22/01	69	265	0.58	5.7								
MW-415	10/23/01	361	189	0.49	5.4								
MW-421	10/22/01 1/29/98	239	16	0.03	7.3	<0.2	8.05	<0.05	<2	102	2.7	<1	1.24
MW-452	10/23/01 1/22/98	163	239	1.43	7.0	<0.2	<0.1	<0.05	<2	90	2.3	<1	0.55
MW-520	10/23/01	405	-154	0.03	8.3								

Table 2.3 Chlorinated Ethenes and Ethanes Concentrations in Selected Wells Near Pilot Area

Well		MW-415			MW-406		
Date		10/23/2001	5/3/2002	10/21/2002	10/22/2001	4/26/2002	10/17/2002
PCE	µg/L	114300	116220	123564	56700	9543	10700
TCE	µg/L	1131	1434	464	123	66.5	144.1
cDCE	µg/L	849	1015		64.1	29.1	82.1
tDCE	µg/L	20.2			1.2		
VC	µg/L	49.8	5.55		<1		1.04
1TCA	µg/L	3251	3942	3611	2990	329	501.3
1DCE	µg/L	13610	30650	10688	17750	2151	4331
1DCA	µg/L	901	1626	600	84	60.4	160.3
2DCA	µg/L	164	398		24.4	16.3	41.5
CA	µg/L	<1			<1		
TCFM	µg/L	603	2325		167	200.7	335.3
PCE	µM	689	701	745	342	58	65
TCE	µM	8.6	10.9	3.5	0.94	0.51	1.10
cDCE	µM	8.8	10.5	0.0	0.66	0.30	0.85
tDCE	µM	0.21			0.01		
VC	µM	0.161	0.018	0.000	<0.016	<0.016	<0.016
Sum CE	µM	707	722	749	344	58	66
1TCA	µM	24	30	27	22	2	4
1DCE	µM	140	316	110	183	22	45
1DCA	µM	9.1	16.4	6.1	0.8	0.6	1.6
2DCA	µM	1.66	4.02	0.00	0.25	0.16	0.42
CA	µM	<0.016	<0.016	<0.016	<0.016	<0.016	<0.016
Sum CA	µM	176	366	143	207	25	50
TCFM	µM	4.4	16.9	0.0	1.2	1.5	2.4
PCE	% CE	97.5	97.0	99.5	99.5	98.6	97.1
TCE	% CE	1.2	1.5	0.5	0.3	0.9	1.6
cDCE	% CE	1.2	1.5	0.0	0.2	0.5	1.3
tDCE	% CE	0.0			0.0		
VC	% CE	0.0	0.0	0.0	0.0	0.0	0.0
1TCA	% CA	13.9	8.1	18.9	10.8	9.7	7.4
1DCE	% CA	80.0	86.4	76.9	88.6	87.3	88.5
1DCA	% CA	5.2	4.5	4.2	0.4	2.4	3.2
2DCA	% CA	0.9	1.1	0.0	0.1	0.6	0.8
CA	% CA	0.0	0.0	0.0	0.0	0.0	0.0
		%		%	%	%	%
	Solubility	Solubility	% Solubility	Solubility	Solubility	Solubility	Solubility
PCE	150,000	76.2	77.5	82.4	37.8	6.4	7.1
TCE	1100000	0.1	0.1	0.0	0.0	0.0	0.0
cDCE	3500000	0.0	0.0	0.0	0.0	0.0	0.0
VC	2763000	0.0	0.0	0.0	0.0	0.0	0.0
1TCA	1495000	0.2	0.3	0.2	0.2	0.0	0.0
1DCE	5710000	0.2	0.5	0.2	0.3	0.0	0.1
1DCA	5060000	0.0	0.0	0.0	0.0	0.0	0.0
2DCA	4420000	0.0	0.0	0.0	0.0	0.0	0.0
CA	5710000	0.0	0.0	0.0	0.0	0.0	0.0
TCFM	1080000	0.4	1.6	0.0	0.1	0.1	0.2

“The leaky aquifer solutions yielded transmissivity values of 330 and 342 gallons per day per foot (gal/day/ft). The Theis recovery solution for the confined model yielded a similar value. Recharge from the rain event that occurred during the pumping portion of the test was apparent in the recovery curve, since the curve indicates zero drawdown at a t/t' value of greater than 2 instead of passing through the origin of the diagram.

“Therefore, the higher transmissivity (T) values determined from the combined aquifer solutions (up to 494 gallons per day per foot for the unconfined model) may be the least representative of true aquifer parameters. Hydraulic conductivity (K) values determined for the various pumping test solutions typically were three to four times higher than K values determined from slug tests of monitoring wells located within or close to the source area (Well No.'s 405, 406, 410, 415, and 416).

"The average K value of the leaky aquifer solution of 15.2 gallons per day per square foot (gal/day/ft) was used to determine the natural groundwater flow velocity in the SWMU 10 source area. Using an estimated effective porosity of 0.2 for the sand aquifer and a gradient of 0.00343 feet per foot from Well No. 415 to Well No. 403, a natural groundwater flow velocity of 0.03 feet per day (12 feet per year) was determined.”

A geological cross section from the CH2MHill (1999) DNAPL Investigation is shown in Figure 2-3. Based on the information provided in the reference material obtained from ArAFB, it appears that there is a general separation between contaminant fate and transport in the shallower and deeper zones in this vicinity of the site.

After the pilot test injections have been made, new hydraulic conductivity measurements will be collected and will be compared to previous hydraulic conductivity measurements prepared during previous investigations at the sites. These analyses will be performed just prior to the introduction of the edible oil substrate and will serve as a baseline for evaluating performance of the test. The results will be used to evaluate the impact of introducing the soybean oil on the subsurface transmissivity. Additional discussion of hydraulic conductivity testing is provided in Section 2.4.5.

The following information is excerpted from the CH2MHill (1999) SWMU-10 DNAPL Delineation Report. It describes the relevant hydrogeology of the SWMU 10 contaminant plume.

“The shallow aquifer beneath SWMU 10 consists of a well-graded sand/gravel layer interbedded with sandy clay, coarse sand, and fine gravel lenses. These lenses range in thickness from greater than 1 foot to less than an inch. The sand/gravel layer is approximately 15- to 25-feet thick beneath the site, and the top of the layer lies at an approximate depth of 15 feet below the surface. Thin layers (0.1- to 0.5-foot thick) of a fractured coarse-grained sandstone were encountered at depths ranging from 8 to 17 feet bgs. However, based on the geologic interpretation of soil boring logs, the sandstone layers do not appear to be continuous beneath the site. A lean clay/silty clay layer with occasional gravel and sand was encountered at depths ranging from 27 to 32 feet bgs. The clay layer varies in thickness from approximately 1 foot to greater than 4 feet and may not be continuous beneath the source area. This clay layer may be a distinct unit from the clay layer that separates the shallow aquifer from the lower intermediate aquifer, found at a depth of approximately 40 feet bgs....

“The potentiometric surface of the shallow aquifer occurs at a depth of approximately 12 feet bgs, with groundwater generally flowing toward the northeast within the aquifer. The average hydraulic conductivity of the shallow aquifer is approximately 5.9×10^{-4}

centimeters per second (cm/sec), with an estimated average flow velocity of 19 feet/year.”

2.3 SUBSTRATES AND TRACERS

The following materials will be injected during pilot tests of the edible oil remediation process. All added materials will be food-grade, Generally Recognized as Safe (GRAS) materials. Chemical properties of these compounds are shown in Table 2-4.

Edible Oil Organic Substrate -Soybean Oil: Food grade soybean oil will be obtained in 55-gallon drums from a commercial supplier such as Oleocal IVO-114, Lambent Technologies Corporation, Stokie, IL. The specific gravity of soybean oil is 0.925 g/cc at 70°F which calculates to 7.7 pounds per gallon. Product sheets and a Material Safety Data Sheet (MSDS) for soybean oil are provided in Appendix I. Soybean oil will be injected into both pilots.

Emulsifying Agents-Polysorbate 80 and Glycerol Monooleate: Lumisorb PSMO-20 POE (20) Sorbitan Monooleate and Lumulse Glycerol Monooleate will be obtained from Lambent Technologies of Stokie, IL. The density of the Lumisorb PSMO-20 POE (20) Sorbitan Monooleate is 1.08 g/cc or 9.0 lb/gallon and it has a hydrophilic-liphophic balance (HLB) of 15. The density of the Lumulse Glycerol Monooleate is 0.94 g/cc or 8.0 lb/gallon and it has a HLB of 3.4. Product sheets and Material Safety Data Sheets (MSDS) for Lumisorb PSMO-20 and Lumulse Glycerol Monooleate are provided in Appendix I. Chemical properties of these emulsifying agents are shown on Table 2-4. The surfactant mix will contain 56% Glycerol Monooleate, 38% Lumisorb PSMO-20 POE (20) Sorbitan Monooleate, and 6% water. The surfactant mix will only be used with the PRBB pilot 2. The MSDS for the two surfactants are provided in Appendix I.

Sodium Lactate: Envirolac 60, a 60% sodium lactate ($C_3H_5O_3Na^+$) solution with a specific gravity of 1.31 to 1.34 and a molecular weight of 112, will be obtained from Purac America, (South Plainfield, NJ). The sodium lactate will only be used with the PRBB pilot 2. A MSDS for sodium lactate is provided in Appendix I.

Nutrient Amendment-Yeast Extract: Yeast extract is a dry powder available from DSM Foods Specialties USA, Eagleville, PA. Yeast extract is a common ingredient in microbiological preparations providing trace nutrients to enhance cell growth. Yeast extract will only be used with the PRBB pilot 2. Appendix I contains a MSDS for Yeast Extract.

Inorganic Tracers-Sodium Bromide: Sodium bromide (NaBr) tracer will be used to enable monitoring of the movement of groundwater away from the injection points that compose the PRBB. Sodium bromide is a salt (molecular weight = 103) with high solubility in water that can be readily monitored with field and laboratory instrumentation. Sodium bromide (Photosystems, Inc., Dexter, MI) will be mixed into the water to be injected prior to using the groundwater for injection or flushing of the substrate. A tracer concentration of approximately 100 mg Br/L (molecular weight of bromide = 80) will be introduced so that the presence of Br^- will be readily detectable in groundwater sampled from the downgradient monitoring wells. The MSDS for sodium bromide is provided in Appendix I. Sodium bromide will be added to the emulsion and chase water used in PRBB pilot 2.

Table 2.4 Chemical Properties Table

Compound	CAS No.	Vapor Pressure	Henry's Law Constant	Log Octanol/Water Partition Coefficient	Aqueous Solubility	Molecular Weight	Density at 20 °C
Units		mm Hg	atm-m ³ /mole	none	mg/L	none	g/mL
Tetrachloroethene	127-18-4 (1)	18.5 at 25 °C (1)	0.015 (1)	3.40 (1)	150 at 25 °C (1)	165.8 (1)	1.62 (2)
Trichloroethene	74-01-6 (1)	69.0 at 25 °C (1)	0.010 (1)	2.42 (1)	1,100 at 25 °C (1)	131.4 (1)	1.46 (2)
Cis-1,2-Dichloroethene	156-59-2 (1)	200 at 35 °C (1)	0.0034 (1)	1.86 (1)	3,500 at 25 °C (1)	96.9 (1)	1.28 (2)
Vinyl Chloride	75-01-4 (1)	2,660 at 25 °C (1)	0.011 (1)	1.38 (1)	2,763 at 25 °C (1)	62.5 (1)	0.91 (2)
Trans-1,2-Dichloroethene	156-60-5 (1)	340 at 25 °C (1)	0.0067 (1)	2.06 (1)	6,300 at 25 °C (1)	96.9 (1)	1.28 (2)
1,1,1-Trichloroethane	71-55-6 (1)	124 at 25 °C (1)	0.008 (1)	2.49 (1)	1,495 at 25 °C (1)	133.4 (1)	1.34 (2)
1,1-Dichloroethane	75-34-3 (1)	227 at 25 °C (1)	0.0059 (1)	1.79 (1)	5,060 at 25 °C (1)	99.0 (1)	1.18 (2)
1,1-Dichloroethene	75-35-4 (1)	591 at 25 °C (1)	0.030 (1)	2.13 (1)	250 at 25 °C (1)	96.9 (1)	1.21 (2)
1,2-Dichloroethane	107-06-2 (1)	78.7 at 25 °C (1)	0.00098 (1)	1.48 (1)	8,524 at 25 °C	99.0 (1)	1.26 (2)
Chloroethane	75-00-3 (1)	766 at 12.5 °C (1)	0.0085 (1)	1.43 (1)	5,710 at 20 °C (1)	64.5 (1)	0.898 (1)
Trichlorofluoromethane	75-69-4 (2)	803 at 25 °C (1)	0.097 (1)	2.53 (1)	1,080 at 30 °C (1)	137.4 (1)	1.49 at 17 (2)
Ethene	74-85-4 (2)					28.0 (2)	0.00115 (2)
Ethane	74-84-0 (2)				58.7 at 20 °C	30.1 (2)	0.00123 (2)
Methane	74-82-8 (2)				23.5 at 17 °C (2)	16.0 (2)	0.000654 (2)
Carbon Dioxide	124-38-9 (2)				1,610 at 20 °C	44.0 (2)	0.0018 (2)
Soybean Oil	8001-22-7 (2)						0.92 (2)
Lumisorb PSMO-20	9005-65-6 (3)	<1 at 25 °C			Soluble (3)		1.07 (3)
Lumulse GMO FGK	37220-82-9	<1 at 25 °C			Insoluble	356.6 (3)	0.96 (3)
Sodium Bicarbonate	144-55-8				90900 at 25 oC (2)	84 (2)	
Sodium Bromide	7647-15-6				90900 at 25 oC (2)	103 (2)	
Sodium Lactate	72-17-3				Soluble (3)	112.1 (2)	1.31 (3)
Yeast Extract	232-387-9				200,000 (3)		

(1) P. H. Howard. 1990-1993. Handbook of Environmental Fate and Exposure Data for Organic Chemicals. Volumes I, 2, and IV. Lewis Publishers, Chelsea, MI.

(2). Windholz, M. 1983. The Merck Index. An Encyclopedia of Chemicals, Drugs, and Biologicals. Merck and Co., Rahway, NJ.

(3) MSDS and Product Sheets.

pH Buffer – sodium bicarbonate: sodium bicarbonate (Coyne chemicals, pa) will be added to the emulsion Ph to increase the pH of the groundwater which ranges from 5.0 to 5.7 in the surrounding wells. Approximately 1,000 mg/L of sodium bicarbonate will be added to the emulsion and chase water. A MSDS for sodium bicarbonate is included in Appendix I.

2.4 PILOT TESTS

2.4.1 Site-Specific Planning

Approval from the AFCEE's Contracting Officer's Representative (COR) will be obtained prior to initiation of fieldwork at the site. Prior to the start of the pilot tests at ArAFB, a kick-off meeting will be held to coordinate activities and ensure that all base-specific health, safety and regulatory concerns are addressed. The kick-off meeting may be conducted as a conference call between the site representative at ArAFB, Solutions-IES, TSI and the COR at AFCEE.

Two pilot tests are planned for Arnold AFB. Pilot Test #1 will evaluate DNAPL sequestration with soybean oil as a way to reduce the mass flux discharging from the treated area by: (1) reducing the effective hydraulic conductivity; (2) generating a new mixed soybean oil-PCE/TCE NAPL with a lower effective PCE solubility; and (3) enhancing contaminant biodegradation. Pilot Test #2 will evaluate the effectiveness of a PRBB approach in a high concentration zone. The locations for the two pilots are shown in Figure 2-4.

The source area treatments will be conducted in the northeastern corner of SWMU 10 near well 415. This location is recommended since it is further away from the core of the DNAPL area and would reduce potential adverse impacts on the GWTU air stripper system. However, the possibility remains that over time some soybean oil, its breakdown products and/or emulsifying agents in the area could be drawn to the GWTU with the potential to support biological growth in the air stripper that might increase O&M of that system.

In Pilot Test #1, two injection wells and three monitor wells will be installed. Liquid soybean oil will be injected into the aquifer sufficient to impact a 15 ft vertical thickness by 10 ft diameter assuming 25% effective porosity. Liquid soybean oil is a NAPL with a relatively high viscosity so it is generally more difficult to achieve a uniform distribution throughout the treatment area. Most of the oil preferentially will flow through the higher permeability zones. However, since most of the CAHs will also be in these zones, the sequestration of CAHs and preferential removal from the groundwater should be achieved.

Two two-inch diameter stainless steel injection wells will be installed to a depth of 30 feet bgs with a 15 foot screen using a hollow stem auger or wet rotary drilling. The injection wells will be constructed with a bentonite plug and cement grout well cap to provide a good well seal on the upper section above the screened interval and include a cement seal and sump on the lower section below the screened interval. Three multi-level 2-inch stainless steel monitoring wells will be installed surrounding the injection well at distances of 5, 10, and 15 feet. The Solinst Continuous Multichannel Tubing (CMT) multilevel groundwater monitoring system or an equivalent system will be used. The multilevel sampling points will be screened from 15 to 17 feet, 21 to 23, and 28 to 30 feet bgs. Any pooled DNAPL will be recovered and sent to the DNAPL separation and groundwater treatment unit.

Approximately 2,145 gallons (39 drums) of liquid soybean oil will be injected into the two injection wells at a flowrate sufficient to maintain an injection pressure of 10 to 15 psi. This volume should be equivalent to a 15 ft vertical thickness x 10 ft diameter x 25% porosity. The injection will begin at a low pressure and the injection pressure will be raised to speed the injection flow rate. If the well seal is blown

out, additional bentonite and cement grout will be injected and allowed to set up for one day before additional oil is injected.

For Pilot Test #2, the relatively short PRBB will be created in a high concentration zone by injecting soybean oil emulsion through a row of four injection wells spaced 7.5 feet apart. The pilot barrier test will be conducted in the area to the west of well 415 and between boring locations TSB8-13 and TSB8-14. The four injection wells and six monitoring wells for Pilot Test #2 will be installed using hollow-stem auger or wet rotary drilling techniques. The polyvinyl chloride (PVC) injection and monitoring wells will be screened between 25 and 40 feet bgs. Prior to any well drilling, both ArAFB and the local utility company will be contacted to provide work clearances in the test area. Any permits required by ArAFB will also be obtained.

For Pilot Test #2, a soybean oil emulsion will be injected into the treatment zone followed by water flushing to distribute and immobilize the oil. Injection flow rates and pressures will be monitored throughout the injection cycle. Contaminant concentrations will be monitored over time in both the injection wells and nearby monitoring wells.

2.4.2 Water Supply

Water for preparation of the oil-in-water emulsion distribution in the subsurface will be obtained from the groundwater treatment system. The treated groundwater will be stored in polypropylene tanks. The emulsion will be pushed away from the injection wells with approximately one pore volume of bromide amended water. Although using groundwater is the preferred approach, should it be logistically impossible to obtain enough water in this way, an alternative water supply such as a nearby fire hydrant, will be considered. Groundwater samples will be collected before and after the emulsion injection. While dilution of the groundwater contaminants will occur, the pre- and post- injection samples and the bromide tracer should help to quantify the effects of dilution with the emulsion and chase water.

2.4.3 Sequestration Pilot Test #1

Pilot Test #1 will be conducted in the DNAPL-contaminated area near well 415 (Figure 2-5). The final location of the injection wells will be made in conjunction with ArAFB representatives, taking into account concentrations of groundwater contaminants at the location, presence of existing wells that may be used in the test, proximity to the existing groundwater recovery system, proximity to an available water source, underground and aboveground utilities, site access and potential disruption to base operations.

The CH2MHill Soil Boring Log (Figure 2-6) for well 415 shows interbedded clay, silty clay, and silty fine sand to final depth of 40 feet. In October 2001 (ACS 2002), well 415 contained very high levels of PCE as well as elevated concentrations of 1TCA, TCE, cDCE, tDCE, VC, 1DCE, and 1DCA. In addition, 2DCA and TCFM were also detected in the groundwater. A nearby soil boring TSB8-6 installed during the DNAPL investigation (CH2MHill 1999) tested negative for the presence of DNAPL using the Sudan IV test at 15 to 20 feet and 25 to 30 feet. A sample collected at 28 to 29 ft bgs contained 0.032 mg/kg PCE and 0.0024 mg/kg 2TCA, with no detectable (detection limit 0.0014 mg/kg) 1DCA, 1DCE, 1TCA, or TCE.

The water table in well 415 fluctuates from a high of 1070 feet mean sea level (msl) in May to a low of 1057.6 feet msl in October or about 12 feet seasonally. Injection will occur in the fall during the seasonal groundwater low. AEDC (2000) reported that in June 2000 following pumping of wells 402, 511, 512, 513, 514, 515, 517, and 522 at a combined flow of 1.72 gpm for 25 days, a drawdown of up to 9.9 feet

was found between upgradient well 290 and well 516 (Figure 2.7). The cone of depression extended as far away as 450 feet.

2.4.3.1 Substrate Injection Point

Two two inch stainless steel injection wells will be installed using hollow stem auger or wet rotary drilling to a depth of 33 feet bgs and will be screened from 15 to 30 ft bgs with 0.20 slot well screen (Figure 2-8). Any boring logs generated during installation of the injection or monitoring wells will be provided to AFCEE and Arnold AFB. The injection wells will be finished with a three-foot sump and endcap set in cement, a sandpack surrounding the screened interval with the remaining annular space sealed with bentonite and cement grout to the surface. Each injection well will be finished with a below grade protective cover. At the completion of testing, all wells will remain as permanent monitoring points available for subsequent testing, should it be requested.

2.4.3.2 Groundwater and Soil Gas Monitoring Wells

Three multi-level Solinst CMT Groundwater monitoring systems will be installed 5, 10, and 15 feet from the injection well as shown in Figure 2-5. A schematic of the Solinst CMT Monitoring system is shown in Figure 2-9. A paper describing the CMT system is included in Appendix II. The monitoring wells will be screened with sampling ports from 15 to 17 feet, 21 to 23, and 28 to 30 feet. Fine filter sand will be used to pack the screen followed by 14 feet of bentonite/cement grout to the surface. Each monitor well will be finished with a below grade protective cover. Monitor wells will be given designations by the ArAFB project representative. For the purpose of this work plan, these new monitoring wells will be identified as MW-A, MW-B, and MW-C. Sampling ports for the multi-level wells will be designated as 16, 22, and 29 feet. A soil gas monitoring point (SG-1) will be installed to a depth of ten feet bgs.

2.4.3.3 DNAPL Recovery

Bottom-lift pneumatic pumps will be installed into each injection and monitoring well to recover any pooled DNAPL. The DNAPL and groundwater will be sent to the existing DNAPL separation and water treatment system. Recovered DNAPLs will be characterized with respect to composition, density, viscosity, and interfacial tension. Arnold AFB has agreed to arrange for disposal of any recovered DNAPL, DNAPL-soybean oil, or DNAPL-soybean oil emulsion through their on-going contract.

2.4.3.4 Substrate Distribution Plan

Once DNAPL recovery has stopped, approximately 2,145 gallons (39 drums or 7.8 two hundred seventy-five gallon tots) of liquid soybean oil (Oleocal IVO-114, Lambent Technologies Corporation, Stokie, IL or equivalent) will be injected into the injection wells at a flowrate sufficient to maintain an injection pressure of 10 to 15 psi. This volume should be equivalent to a 15 ft vertical thickness x 10 ft diameter x 25% porosity. The injection will begin at a low pressure and the injection pressure will be raised to speed the injection flow rate. If the well seal is blown out, additional bentonite and cement grout will be injected and allowed to set up for one day before additional oil is injected.

A diagram of the injection process for the soybean oil is shown in Figure 2-10. The injection system and the injection well will be filled with groundwater to remove entrapped air and the system pressure-tested. Then the soybean oil will be injected. If possible, each injection well will receive 1072.5 gallons of soybean oil. The volume of oil injected into each injection well will be recorded.

2.4.3.5 Substrate Recovery Plan

At this time, soybean oil recovery is not planned. The oil is assumed to stay in place. Periodic sampling of NAPLs accumulated in wells will be conducted to determine composition, density, viscosity, and interfacial tension profiles. However, if soybean oil accumulates in nearby wells such as Well 415 or one of the extraction wells and the density of the NAPL is greater than 0.99 g/ml, then oil recovery may be necessary. An oil skimmer can be used to collect the oil or it can be done manually with a bailer or product pump. The DNAPL-impacted soybean oil and groundwater could be sent to a portable oil-water separator. The soybean oil would be sent to an outside contractor for disposal. Greg Sandlin of ATA has stated that the ArAFB will handle the disposal. If soybean oil makes it into the groundwater recovery and treatment system, it should be possible to pump it from the top of the separation tank.

2.4.3.6 Hydraulic Conductivity Tests

One of the objectives of the sequestration test is to reduce the hydraulic conductivity of the formation. Slug tests, in situ capacity tests, and/or borehole dilution tests will be conducted before and after oil emplacement to determine the effect of the oil injection on the hydraulic conductivity of the formation. Hydraulic conductivity testing will require that a short-term shutdown of the hydraulic containment system.

2.4.3.7 Groundwater Monitoring Plan

Before and after the injection of soybean oil and during subsequent sampling events, water levels in injection and monitor wells will be measured and recorded. Changes in head in adjacent injection wells will be monitored during the injection process. In addition, any accumulation of soybean oil on the groundwater surface will be measured with an oil-water interface probe. Samples of the soybean oil will be analyzed periodically for VOCs, density, viscosity, and interfacial tension. Changes in contaminant concentrations, electron acceptors, electron donors and indicator parameters with time will be monitored in the injection well and the three monitor wells (MW-A, MW-B, and MW-C). The monitoring and injection wells will be sampled after installation, after injection, and then after 6, 12, 18 and 24 months. Additional details of the monitoring program are described in Section 3.0.

2.4.3.8 Contaminant Mass Flux Evaluations

The effects of oil injection due to the combined effects of contaminant sequestration and enhanced biodegradation will be evaluated using conventional groundwater contaminant concentration data over time. However, these evaluations may be confounded as a result of continued replenishment of dissolved contaminants from DNAPL source materials. In other words, groundwater samples from discrete monitoring wells only give an indication of concentrations in a very localized area. Any source of sorbed or residual phase DNAPL sources near a monitoring well may mask sequestration or enhanced biodegradation effects occurring a small distance upgradient. In contrast, a groundwater extraction system like the one at SWMU 10 extracts a much larger volume of groundwater over time and can provide a more integrated profile of relative changes in contaminant flux across the sequestration Pilot Test Area #1. Thus, contaminant concentrations, flow rates, and cumulative groundwater extracted data from groundwater extraction wells located adjacent to Pilot Test Area #1 will be useful in evaluating changes in contaminant flux. Past and future groundwater extraction system operation, sampling, and analysis data will be discussed and evaluated in an effort to determine if any changes in contaminant flux are observed due to vegetable oil injection. It is anticipated that past and future operation data collected as part of the groundwater extraction system operation will provide most of the data required to conduct these analyses. However, this evaluation may require changes to flow rate and wellhead contaminant

concentration sampling procedures. Periodic sampling of well MW-415 and the new injection and monitoring wells will be conducted as part of AFCEE's project. Nearby wells will not be sampled as part as this program. However, data from Arnold AFB's ongoing monitoring program will be incorporated into the interpretation of the results of the pilots. Potential changes to groundwater extraction system monitoring procedures will be discussed with Arnold AFB and system operations staff.

2.4.4 Permeable Reactive Biobarrier Pilot Test #2

Pilot Test #2 will be conducted in the upper contaminated zone northeast of well 415 outside of SWMU 10 (Figure 2-10). The pilot barrier test will be conducted in the area to the west of well 415 and between boring locations TSB8-13 and TSB8-14. In Pilot Test #2, a barrier of four injection wells spaced 7.5 feet apart will be treated with soybean oil emulsion to evaluate the effects of this treatment on reductive dechlorination of PCE and 1TCA to the non-toxic end-products ethene and ethane. To carry out this test, four new injection wells and six monitor wells will be installed to follow the progress of the test. DNAPL was not found with the Sudan IV test procedure in either TSB13 or TSB14 (CH2M Hill 1999). PCE concentrations in the soil samples from 25 to 35 ft bgs in these borings ranged from 2,600 to 5,400 mg/kg with lower concentrations of 1,1-DCE (<170 to 500 mg/kg) and no detectable 1DCA, 1TCA, 2TCE, or TCE.

2.4.4.1 Soil Gas Monitoring

Pilot Test #2 will be conducted in the upper unconfined unit. As a consequence, there is a potential for accumulation of VOCs (methane, vinyl chloride, and other volatile gases) in the unsaturated zone overlying the aquifer. As shown on Figure 2-10, one soil-gas monitoring point (designated SG-2) will be installed approximately 3 ft bgs and another soil-gas monitoring point (designated SG-3) will be installed approximately 10 ft bgs. The gas monitoring points will be constructed by drilling to depth and installing a 2-foot long section of 2-inch PVC well screen attached to riser. The gas monitoring wells will be completed with a sandpack around the screened interval. The remaining annular space will be sealed with bentonite and cement grout to the surface. The casing will be terminated below grade with a petcock or small valve to facilitate collection of soil gas samples. Each sampling point will be finished with a flush-mount protective manhole cover.

2.4.4.2 Substrate Injection Points

Four new substrate injection wells will be installed outside of the SWMU 10 area approximately 25 feet to the east of well 415. The injection wells will be installed using hollow stem auger drilling and spaced 7.5 feet on center. The 2 inch PVC injection wells will be installed to a depth of 40 feet and will be screened from 25 to 40 ft bgs with 0.20 slot screen (Figure 2-11). The injection well will be finished with a sandpack surrounding the screened interval with the remaining annular space sealed with bentonite and cement grout to the surface. Each injection well will be finished with a below grade protective cover. As shown in Figure 2-10, the wells will be designated IW-2, IW-3, IW-4, and IW-5, or other designation preferred by the ArAFB project representative. At the completion of testing, all wells will remain as permanent monitoring points available for subsequent testing, should it be requested.

2.4.4.3 Groundwater Monitoring Wells

Six 2-inch PVC monitoring wells will be installed by hollow stem auger drilling as shown in Figure 2-11. Two wells will be installed upgradient of the row of injection wells (to the east assuming that the groundwater flow is towards the recovery wells) at 10 and 15 feet away from the barrier and four wells downgradient of the barrier at 5, 10, 15, and 20 feet. The monitoring wells will be screened from 25 to 40 feet. Fine filter sand will be used to pack the screen followed by 25 feet of bentonite/cement grout to the

surface. Each monitor well will be finished with a below grade protective cover. Monitor wells will be given designations by the ArAFB project representative. For the purpose of this work plan, these new monitoring wells will be identified as MW-D, MW-E, MW-F, MW-G, MW-H, and MW-I.

2.4.4.4 Substrate Distribution Plan

The Pilot Test #2 will be conducted by treating the four injection wells with the soybean oil-in-water emulsion. The emulsion preparation and injection process for Pilot Test #2 is described below.

For Pilot Test #2, a soybean oil emulsion will be injected into the treatment zone followed by water flushing to distribute and immobilize the oil. Injection flow rates and pressures will be monitored throughout the injection cycle. Contaminant concentrations will be monitored over time in both the injection wells and nearby monitoring wells.

The substrate requirements for the Biobarrier Pilot #2 were estimated based upon the electron donor demand for competing electron acceptors (measured dissolved oxygen, nitrate, and sulfate concentrations with production of an estimated 20 mg/L of ferrous iron and 10 mg/L methane), dissolved contaminants, release of 100 mg/L of organic carbon, and the estimated groundwater flow rate through a 7.5 foot wide diameter cylinder 15 feet deep with a porosity of 0.25. Appendix III shows the calculations.

Edible oil emulsion will be injected into the four injection wells in the biobarrier. The emulsion will be prepared by combining approximately 55 gallons of soybean oil (Oleocal IVO-114, Lambent Technologies Corporation, Stokie, IL), 5.5 gallons of food grade surfactant (Lumisorb PSMO-20 Sorbitan Monooleate and Lumulse Glycerol Monooleate from Lambent Technologies of Stokie, IL), 6.1 pounds of sodium bromide (Photosystems, Inc. of Dexter, MI), and 5,420 gallons of treated groundwater and creating a fine emulsion. Sodium bromide will be used as a non-reactive tracer to monitor the movement of the injection fluid. Lactate (0.66 gallons of 60% sodium lactate from Purac America, Chicago, IL) and 0.92 pounds of yeast extract (DSM Foods Specialties USA, Eagleville, PA) will be added to the emulsion as a rapidly degradable substrate and a source of vitamins and trace minerals. All added substrates will be food-grade, Generally Recognized as Safe (GRAS) materials.

A batch of 220 gallons of emulsion will be prepared in a 275 gallon tank (Figure 2-12). The emulsion will be prepared by adding 5.5 gallons of the surfactant mix to 165 gallons of treated groundwater while circulating water through the Silverson High Shear Mixer (a product description of the Silverson High Shear Mixer is shown in Appendix II). Then 55 gallons of soybean oil will be added. The batch of emulsion will be amended with 107 g (0.24 pounds) sodium bromide, 2.5 L (0.66 gallons) of 60% sodium lactate, and 416 g (0.92 pounds) of yeast extract. Fine droplets will be prepared by passing the fluid at least five times through the Silverson High Shear Mixer. The stability of the emulsion will be checked by allowing an aliquot to sit for one hour. As another check for stability, approximately 250 mL of emulsion will be passed through a twelve inch long 2 inch diameter column packed with site soil. The emulsion will be considered to be stable if it does not separate after one hour and if can pass through the soil column.

The emulsion will be injected into each injection well. A circulation loop will be prepared so that multiple wells can be injected simultaneously. If possible, injection will be into two non-adjacent wells. A flow meter and control valve will be used for each well. Emulsion that is not injected will be recirculated back into the tank. Injection pressures at each injection well will be maintained below 15 psi with flow rates of less than 2 gpm. If the emulsion pressure is too high and there is evidence of breakthrough to the surface, then we will switch to another injection well. After pressures have stabilized at the initial injection well, additional emulsion will be injected at a lower flow rate and pressure. Once

the 55 gallons of emulsion has been introduced into an injection well, 1,355 gallons of treated groundwater containing 660 g (1.5 pound) of sodium bromide will be injected to further disperse the emulsified soybean oil.

2.4.4.5 Groundwater Monitoring Plan

Before and after the emplacement of emulsion and during subsequent sampling events, water levels in injection and monitor wells will be measured and recorded. In addition, any accumulation of oil emulsion LNAPL on the groundwater surface will be measured with an oil-water interface probe. Changes in contaminant concentrations, electron acceptors, electron donors and indicator parameters with time will be monitored in two injection wells (IW-3 and IW-5), the six new monitor wells, and well 415. The monitoring and injection wells will be sampled after installation, after injection, and then after 6, 12, 18 and 24 months. Details of the monitoring program are described in Section 3.0.

2.4.5 Hydraulic Conductivity Testing

To evaluate the impact of the injection of the soybean oil emulsion on the hydraulic conductivity of the aquifer, the hydraulic conductivity of the aquifer will be measured in selected injection and monitor wells at each pilot test location. Hydraulic conductivity measurements will be performed using standard slug-in and slug-out tests or specific capacity tests. Data will be reduced using standard Bouwer-Rice methodology.

In situ hydraulic conductivity will be measured at three different times during the pilot test program. Measurements will be collected: 1) after the installation of the test barrier and monitoring points are complete, 2) after the introduction of substrate, and 3) at one later sampling interval during the course of the monitoring program (e.g., 6 months). Hydraulic conductivity tests will be conducted on the following wells. Hydraulic conductivity testing will require a short-term shutdown (e.g. 3-4 days) of the hydraulic containment system. Arnold AFB has approved this short shutdown.

Table 2-5. Identification of Wells Scheduled for Hydraulic Conductivity Measurements at Each Pilot Test Location		
Well Location	Pilot Test #1	Pilot Test #2
Injection Wells	IW-1	IW-3 and IW-5
Monitoring Wells	MW-A and MW-C	415, MW-D, MW-H, and MW-F

Hydraulic conductivity will be evaluated with slug tests or by determining the maximum sustained yield. Groundwater will be withdrawn at the maximum sustained flowrate and this flowrate will related to the hydraulic conductivity.

3.0 SAMPLING AND ANALYSIS PLAN

3.1 MONITORING PLAN

As described in Sections 2.4.3 and 2.4.4 above, one new injection well and three new monitoring wells will be installed for Pilot Test #1 and four new injection wells and six new monitoring wells will be installed at Pilot Test #2. Wells IW-1, IW-3, IW-5, MW-A, MW-B, MW-C, MW-D, MW-E, MW-F, MW-G, MW-H, and MW-I will be sampled immediately after all new installations have been completed to serve as a baseline for future comparison. Groundwater samples will be analyzed for chlorinated aliphatic hydrocarbons (CAH) contaminants, electron acceptors (oxygen, nitrate, sulfate), phosphate, electron donors (including total organic carbon [TOC] and short-chain fatty acids), light hydrocarbon gases (including ethene [C₂H₄], ethane [C₂H₆], methane [CH₄], and acetylene [C₂H₂]) and indicator parameters (pH, Eh, Fe⁺², , Cl⁻, S⁻) and tracers (Br). Samples of the floating LNAPL will be collected and analyzed for VOCs, light hydrocarbon gases, density, viscosity, and interfacial tension. The two soil-gas monitoring points adjacent to Pilot Test #2 will be tested in the field for the presence of methane. The monitor wells and injection wells will be sampled also after injection of the emulsion and approximately 6, 12, 18 and 24 months after substrate emplacement. Actual dates for follow-up sampling may be adjusted based on the results of the previous monitoring events. The following table identifies the wells to be monitored routinely in the two pilot tests planned for ArAFB.

Table 3-1. Monitoring and Injection Wells Selected for Long-term Monitoring at Two Pilot Test Locations		
Well Location	Pilot Test #1	Pilot #2
Injection Wells	IW-1	IW-3 and IW-5
Monitor Wells	MW-A16, MW-A22, MW-A29, MW-B16, MW-B22, MW-B29, MW-C16, MW-C22, and MW-C29	MW-D, MW-E, MW-F, MW-G, MW-H, MW-I, and 415
Soil Gas Wells	SG-1	SG-2, SG-3
Total Monitoring Points	10 groundwater and 1 soil gas	9 groundwater + 2 soil gas

3.2 SAMPLE COLLECTION AND ANALYTICAL METHODOLOGY

3.2.1 Radius of Influence Testing

After the application of the insoluble substrate has been completed at each of the pilot test sites, the radius of influence away from the injection wells will be evaluated. The information will be utilized to develop injection strategies for future barrier technologies employing this approach. The radius of influence will be evaluated by noting any visual changes such as coloration or milkiness due to the emulsion and analyzing groundwater samples from monitoring well network for TOC and bromide.

Injectant breakthrough testing will be conducted in order to evaluate the distribution of injected reagents during and after the injection process. Injectant breakthrough tests will be conducted via low flow rate pumping of adjacent monitoring wells, flow-through cells, and direct readout field instruments. Flow-through cell parameters will include conductivity, bromide ion-selective electrode, temperature, dissolved oxygen, and oxidation reduction potential. Injectant flow rates will be documented using flow meters and tank gauging.

It is anticipated that the bromide concentration will decrease over the course of the two-year pilot study at each location as a result of the processes of dilution and downgradient migration away from the injection source area. The average groundwater flow velocity in the aquifer has been calculated to be approximately 12 to 19 ft/yr under natural conditions. Therefore, it is likely that bromide introduced with the injection process will have migrated beyond the extent of the furthest-downgradient monitoring wells. For this reason, it may be possible to use bromide as a tracer at this site during future tests. Should bromide continue to be detected in groundwater for an extended period of time, the use of sodium iodide (NaI) may be considered as an alternative tracer (see Section 2.3).

3.2.2 Groundwater Samples from Monitoring Points and Wells

Purging and sampling protocols will follow, in general, the procedures outlined in *Environmental Investigations Standard Operating Procedures and Quality Assurance Manual* (US EPA 1998) or site-specific Arnold QAPP that may be available. Prior to collection of groundwater samples, each well will be purged to remove stagnant water from the well and to allow its replacement by groundwater from the adjacent formation, which is more representative of actual aquifer conditions. The standard protocol for purging each monitoring point will be to measure the depth to groundwater in the well, and then calculate the volume of water in the well based on the total depth of the well and the diameter of the casing. When the volume is known, an adequate purge is achieved when three to five well volumes have been removed.

With respect to groundwater chemistry, an adequate purge is achieved when the pH, specific conductance, and temperature of the groundwater have stabilized. The goals for stabilization are as follows:

- pH- Measurements remain constant within 0.1 Standard Unit (SU).
- Specific Conductance – Measurements vary by no more than 10 percent.
- Temperature – Measurements remain constant for at least three successive readings.

All new wells installed at Pilot Test #1 will be constructed of stainless steel and the new injection and monitoring wells for Pilot Test#2 will be constructed of 2-inch diameter PVC well screen and casing. Because of the expected depth to water, the wells will be sampled using bailers, peristaltic pump, or other pumps. The sequence of sample collection for analysis will be as follows:

- 1) Field parameters:
 - a. Dissolved Oxygen (D.O.);
 - b. Oxidation-Reduction Potential (Redox – Eh);
 - c. pH
 - d. Temperature
 - e. Specific Conductance
 - f. Fe^{+2}
- 2) Laboratory parameters:
 - a. Chlorinated Aliphatic Hydrocarbons (CAH);
 - b. Ethene (C_2H_4), Ethane (C_2H_6), and Methane (CH_4); Acetylene (C_2H_2)

- c. Total Organic Carbon (TOC);
- d. Nitrate, Sulfate, Sulfide; and
- e. Bromide, Chloride
- f. Short Chain Fatty Acids.

Groundwater samples from the monitoring wells will be collected in general accordance with the U.S. EPA EISOPQAM. The use of a low-flow purge and sampling method provides the least stress to the well. Sustained pumping at slow rates usually results in a relatively clear, low turbidity sample. However, for shallow monitor wells, disposable bailers may be used.

The CAHs will be analyzed by Arnold Air Force Base by EPA Method 8240 or EPA Method 8021B and the light hydrocarbon gases by RS Kerr SOP-175 or equivalent methods. Chloride, bromide, nitrate, sulfate, and phosphate will be analyzed by ion chromatography or by standard analytical methods. DOC will also be analyzed by EPA Method 415.2. Microbial characterization of groundwater samples and the investigation for the presence of *Dehalococcoides ethenogenes* will be performed by Microbial Insights, Inc or SiREM Inc. Short chain volatile fatty acids will be analyzed by ion chromatography or gas chromatography.

Iron (Fe^{2+}) and sulfide (S^-) will be analyzed in the field at the time of collection using Chemetrics Field Test Kits (Calverton, VA).

3.2.3 Samples from the Water Supply Wells or Alternate Water Supply

Although it is preferred to use untreated groundwater from the SWMU 10 areas, it may be logistically impossible to accomplish this at ArAFB. Consequently, as stated in Section 2.4.3, an alternate source will be potable water available via nearby fire hydrants. To characterize the water prior to use, a sample will be collected prior to use of this water for the project. The samples will be collected directly from the pumping stream to minimize loss of volatiles. A complete characterization of the water will be prepared including CAHs, electron acceptors (oxygen, nitrate, sulfate, phosphate, Fe^{+2}), donors (DOC), and indicator parameters (pH, Eh, C_2H_4 , C_2H_6 , CH_4 , C_2H_2 , Br^- , Cl^- , S^-). Samples will be collected directly into the appropriate containers. All field measurements for pH, specific conductance, temperature, D.O. redox potential and dissolved iron will be recorded at the time of measurement.

3.3 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC) PROCEDURES

Quality Assurance/Quality Control (QA/QC) procedures will be performed in general accordance with the U.S. EPA EISOPQAM (US EPA 1996b), the U.S. EPA *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water* (US EPA 1998), or base-specific Arnold QAPP, if available.

3.3.1 Sample Handling, Documentation, and Chain-of-Custody

Chain-of-custody procedures are comprised of: 1) maintaining sample custody and 2) documentation of samples for reporting. To document chain-of-custody, an accurate record must be maintained to trace the possession of each sample from the moment of collection to its report of analysis.

At the time of collection, a sample label and field Chain-Of-Custody Record (COC Record) should be completed using waterproof, non-erasable ink. A separate COC Record should be used for each final destination or laboratory utilized during the investigation. The following information must be supplied in the indicated spaces to complete the field COC Record:

- 1) The project number;
- 2) The project name;
- 3) All samplers and sampling team leaders (if applicable) must sign the designated signature block;
- 4) The sampling station number, date, and time of sample collection, grab or composite sample designation, and a brief description of the type of sample and/or the sampling location must be included on each line;
- 5) The analyses that are requested for the sample;
- 6) The name of the sample custodian, if different from the project leader or sampler, should be recorded in the Remarks section of the COC Record;
- 7) The Remarks section should be used to record airbill numbers or other pertinent information.

All samples will be accompanied by the COC Record. The original and one copy of the Record will be placed in a plastic bag inside the secured shipping container if samples are to be shipped. When shipping samples via common carrier, the "Relinquished By" section should be filled in; however, the "Received By" box should be left blank. The laboratory sample custodian is responsible for receiving custody of the samples and will fill in the "Received By" section of the COC Record. One copy of the Record will be retained by the project leader. The original COC Record will be transmitted to the project leader after the samples are accepted by the laboratory. This copy will become a part of the project file.

3.3.2 Field QC Samples

Three types of field QC samples are typically prepared in environmental assessments. These include:

- 1) Trip Blanks – Blanks prepared by the laboratory prior to shipping any laboratory sampling glassware to the site. The Trip Blanks remain with the sampling kits during shipment to the site and are repackaged with samples containing VOCs during the return shipment to the laboratory. Trip Blanks are used to determine if samples were contaminated during storage and/or transportation back to the laboratory. If samples are to be shipped, Trip Blanks are to be provided with each shipment but not for each cooler. Trip Blanks will be prepared with a frequency of one blank per shipment.
- 2) Equipment/Rinse Field Blanks – Equipment/Rinse Field Blanks are collected by running laboratory-supplied organic-free water over and through sample collection equipment. The samples are used to determine if contaminants have been introduced by contact of the sample medium with sampling equipment. The type of installations and sampling activities anticipated at ArAFB will include dedicated or disposable equipment. Where a peristaltic pump is used, Equipment/Rinse Field Blanks will be collected by pumping or pouring laboratory water through a new length of Teflon® tubing that will be used to collect samples from the monitoring wells and collecting the rinsate. Where bailers are used, laboratory water will be poured into the bailer and then collected from the bailer in similar fashion to the collection of groundwater samples. One Equipment/Rinse Field Blank will be prepared to confirm the absence of target contaminants on the sampling equipment.

- 3) Field Duplicate Samples – Field Duplicate Samples are collected from a common sampling location. The purpose of a duplicate sample is to estimate the variability of a given characteristic or contaminant associated with a population. At ArAFB, the frequency of the collection of Field Duplicate Samples will be modified to one sample per sampling event.

3.3.3 Data Analysis and Validation

Samples will be analyzed in accordance with appropriate methodologies as described in the *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water* (US EPA 1996b). Lab samples will be validated by the laboratory prior to reporting. No outside data validation activities will be performed.

Field data will be collected by field instruments or field test kits. Field instruments such as a toxic vapor analyzer, DO meter, pH meter, and conductivity meter will be calibrated each day before use. The record of calibration will be kept in the field notebook. Field test kits such as Hach or Chemetrics are pre-calibrated prior to use. Lot No. and expiration date will be recorded in the field notebook.

3.4 INVESTIGATION-DERIVED WASTE

It is anticipated that several types of investigation-derived waste (IDW) will be generated on this site. These include:

- Personnel protective equipment (PPE)
- Disposable equipment including plastic ground and equipment covers, aluminum foil, tubing, bailers, discarded or unused sample containers, boxes, etc
- Asphalt
- Soil cuttings/drilling muds from well installation
- Groundwater obtained through well development or well purging
- Waste organic substrate solutions
- Cleaning fluids such as detergents, spent solvents and wash water
- Packing and shipping materials

Based on generator knowledge, IDW anticipated at ArAFB may be classified as hazardous. At the time of generation, soil cuttings will be containerized in 55-gallon drums or a roll-off box and staged on site pending analysis and disposal. A composite sample prepared by mixing sub-samples from drums or roll-off will be prepared. The composite samples will be analyzed by Method 8260B for VOCs. Based on the analytical results, the disposition of the IDW will be determined by the ArAFB project representative.

Contaminated groundwater and decontamination fluids from the monitoring wells will be collected in drums as they are generated. The aqueous IDW will then be pumped through a coarse (40 – 50 µm) in-line filter to remove particulates before being transported to the on-site pump and treat remediation system and pumped through the active GWU air stripping/carbon absorption treatment system.

Solid IDW waste such as PPE, bailers, tubing, etc. will be double-bagged and taken to the municipal landfill for disposal. Waste substrate materials such as soybean oil- or lecithin-containing solutions that cannot be used in the injection process will be disposed of via the sanitary sewer system under direction of the ArAFB project representative.

4.0 REPORTING

An interim report will be prepared after one year summarizing the installation and first year data. A detailed report will be prepared summarizing and submitting all site data collected during the pilot test. The report will include:

- Injection system performance and any operational or safety issues of concern;
- Delivery system efficiency;
- Radius of influence;
- Electron acceptor reduction;
- Extent of contaminant dehalogenation;
- Organic carbon release to the downgradient aquifer;
- Electron donor utilization rates; and
- As-built drawings and specifications.
- Appendix containing laboratory data.

Based on this information, the report will detail the overall effectiveness of the pilot system and make objective recommendations regarding the applicable remedial technologies and system expansion.

Cost and performance data will be collected and discussed in the report. The Federal Remediation Technologies Roundtable format (Member Agencies of the Federal Remediation Technologies Roundtable 1998) will be followed.

5.0 SCHEDULE

The milestones for the implementation of the tasks outlined in this work plan are as follows:

- Submit the Work Plan and Health & Safety Plan to AFCEE COR and ArAFB Site Representative
- Review the Work Plan and receive approval to proceed
 - Submit work clearance request to ArAFB engineering 1 month
 - Obtain digging permit 2 weeks
 - Order equipment and supplies for delivery to ArAFB 4 weeks
- Initiate field activities-
 - Install of injection wells and monitoring wells 2 weeks
 - Perform baseline sampling of monitoring and injection wells and obtain hydraulic conductivity measurements 3 days
- Inject the soybean oil and soybean oil emulsion 5-7 days
- Perform follow-up hydraulic conductivity measurements and sampling 3 days
- Conduct first monitoring well sampling & analysis event 6 months
- Conduct second monitoring well sampling & analysis event 12 months
- Prepare Draft Interim Report 13 – 15 months
- Conduct third monitoring well sampling & analysis event 18 months
- Conduct fourth monitoring well sampling & analysis event 24 months
- Prepare report 2 to 3 months

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FIGURES

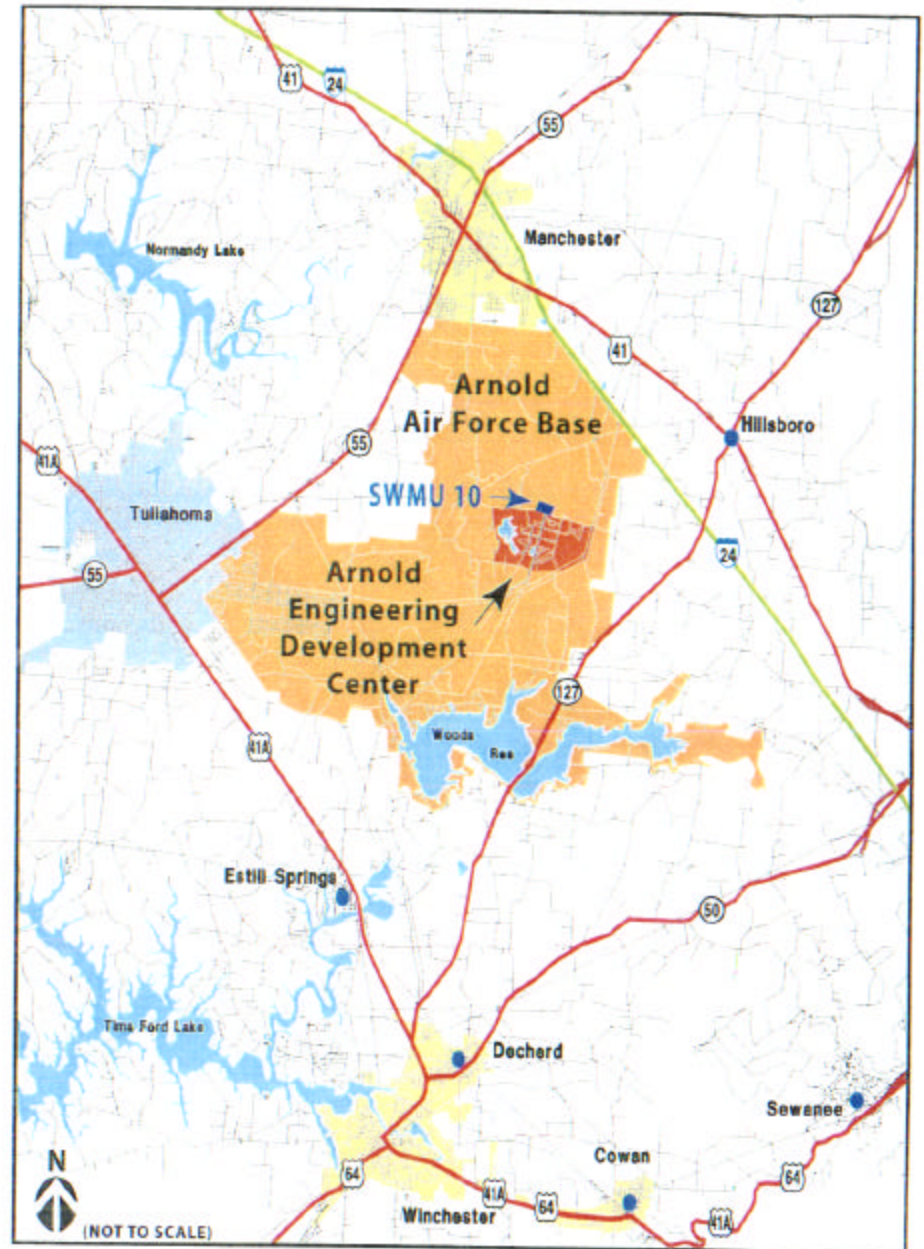


Figure 2-1 Arnold Air Force Base and SWMU 8 Location Maps

LEGEND

- 520Δ Deep Aquifer Monitoring Well
- 455⊕ Intermediate Aquifer Monitoring Well
- 407● Shallow Aquifer Monitoring Well
- 515 • Shallow Extraction Well
- Approximate extent of shallow DNAPL
- Approximate extent of dissolved groundwater contaminants

Compound	4/26/01	10/23/01
1,1-DCA	2.79J	3.44J
cis-1,2-DCE	2.3J	2.52J
Other VOCs	<1	<1

Compound	4/26/01	10/23/01
1,1-DCA	8.84	11.07
1,1-DCE	77	<1
cis-1,2-DCE	8.87	9.32
PCE	1,193	1,817
1,1,1-TCA	35.43	62.71
TCE	9.57	16.79
TCFM	2.01J	4.03J
Other VOCs	<1	<1

Compound	4/26/01	10/22/01
1,1-DCA	10.67	5.42
1,1-DCE	66.12E	<1
cis-1,2-DCE	10.41	5.44
1,1,1,2-PCA	<1	2.71J
PCE	1,310	1,700
1,1,1-TCA	56.24E	119.88
TCE	11.55	10.14
TCFM	2.7J	5.46
Other VOCs	<1	<1

Compound	4/30/01	10/23/01
Chloroform	5.36	3.44J
1,1-DCA	83.99E	76.24
1,2-DCA	24.44	31.86
1,1-DCE	17.747	<1
cis-1,2-DCE	60.41E	24.91
trans-1,2-DCE	1.19J	<1
MCI	8.44	<1
1,1,1,2-PCA	6.55	9.48
1,1,2,2-PCA	4.4J	<1
PCE	760.94E	6,633
1,1,1-TCA	2,990J	631.26
Toluene	1.82J	1.36J
TCE	123.23E	62.31J
TCFM	167.45E	333.25
Other VOCs	<1	<1



Compound	4/30/01	10/23/01
Chloroform	6.17	4.52J
1,1-DCA	141.34E	214.15
1,2-DCA	17.01	19.13
1,1-DCE	929.76E	<1
cis-1,2-DCE	240.49E	206.8
trans-1,2-DCE	3.48J	2.96J
MCI	2.6J	<1
Napthalene	1.07J	<1
1,1,1,2-PCA	1.18J	1.54J
PCE	2,684	2,075
1,1,1-TCA	27.93	59.05
1,1,2-TCA	7.39	7.3
TCE	191.27E	145.14
TCFM	154E	273.31
VC	2.13J	2.08J
o-Xylene	2.52J	<1
Other VOCs	<1	<1

Compound	4/30/01	10/23/01
Carbon Tet.	3.61J	3.16J
Chlorobenzene	2.15J	2.19J
Chloroethane	2.84J	<1
Chloroform	19.01	3J
1,2-DCBz	2.06J	2.42J
1,1-DCA	276.11E	45.28J
1,2-DCA	36.27	34.93
1,1-DCE	12,302	<1
cis-1,2-DCE	297.65	28.02J
trans-1,2-DCE	13.24	2.2J
EBz	1.46J	1.41J
MCI	87.16E	<1
Napthalene	<1	1.45J
1,1,1,2-PCA	76.93E	67.36
1,1,2,2-PCA	9.43	8.58
PCE	32,259	54,502
Toluene	87.53E	84.78J
1,1,1-TCA	23,042	24,186
1,1,2-TCA	38.75	<1
TCE	276.95E	345.15
TCTFE	62.66	<1
TCFM	831.86E	379.13
1,2,4-TMBz	1.24J	3.03J
VC	47.92E	5.82J
m,p-Xylene	4.67J	5.08
Other VOCs	<1	<1

Compound	4/30/01	10/23/01
Acetone	17,500	40.53J
Carbon Tet.	6.27	4.56J
Chlorobenzene	4.59J	4.12J
Chloroethane	10.55	<1
Chloroform	47.03E	5.88
1,2-DCBz	5.21J	2.95J
1,1-DCA	636.95E	173.39
1,2-DCA	87.51E	32.58
1,1-DCE	11,646	<1
cis-1,2-DCE	739.74E	88.74
trans-1,2-DCE	16.71	2.41J
1,2-DCP	1.04J	<1
EBz	9.28	2.52J
MCI	552.12E	<1
Napthalene	1.91J	2.02J
1,1,1,2-PCA	148.79E	161.13
1,1,2,2-PCA	24.61	20.66
PCE	70,495	94,324
Toluene	82.04E	31.39
1,1,1-TCA	11,028	11,264
1,1,2-TCA	72.78	<1
TCE	314.14E	204.58
TCTFE	59.52E	7.68
TCFM	1,013E	790.78
1,2,3-TCP	<1	1.06J
1,2,4-TMBz	2.55J	2.16J
VC	130.23E	6.42J
m,p-Xylene	<1	10.52
o-Xylene	4.41J	1.67J
Other VOCs	<1	<1

Compound	4/30/01	10/23/01
Acetone	525.33E	182.71
Carbon Tet.	<1	1.61J
Chlorobenzene	2.71J	2.18J
Chloroform	54.05E	7.53
1,2-DCBz	2.27J	1.83J
1,1-DCA	467.16E	637.49J
1,2-DCA	163.5E	<1
1,1-DCE	13,609	<1
cis-1,2-DCE	771.94	512.84J
trans-1,2-DCE	20.21	5.07
1,2-DCP	1.88J	5.07
EBz	8	3.31J
MCI	519.43E	<1
Napthalene	1.11J	<1
1,1,1,2-PCA	132.88E	106.88J
1,1,2,2-PCA	72.54E	37.4
PCE	114,430	122,043
Toluene	80.27E	39.51
1,1,1-TCA	3,251	3,981
1,1,2-TCA	131.37E	<1
TCE	550.19E	676.1
TCTFE	21.39	5.13
TCFM	603.09E	2,405
1,2,4-TMBz	1.55J	1.18J
VC	49.77E	5.43J
m,p-Xylene	<1	13.35
o-Xylene	<1	2.52J
Other VOCs	<1	<1

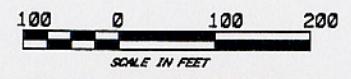
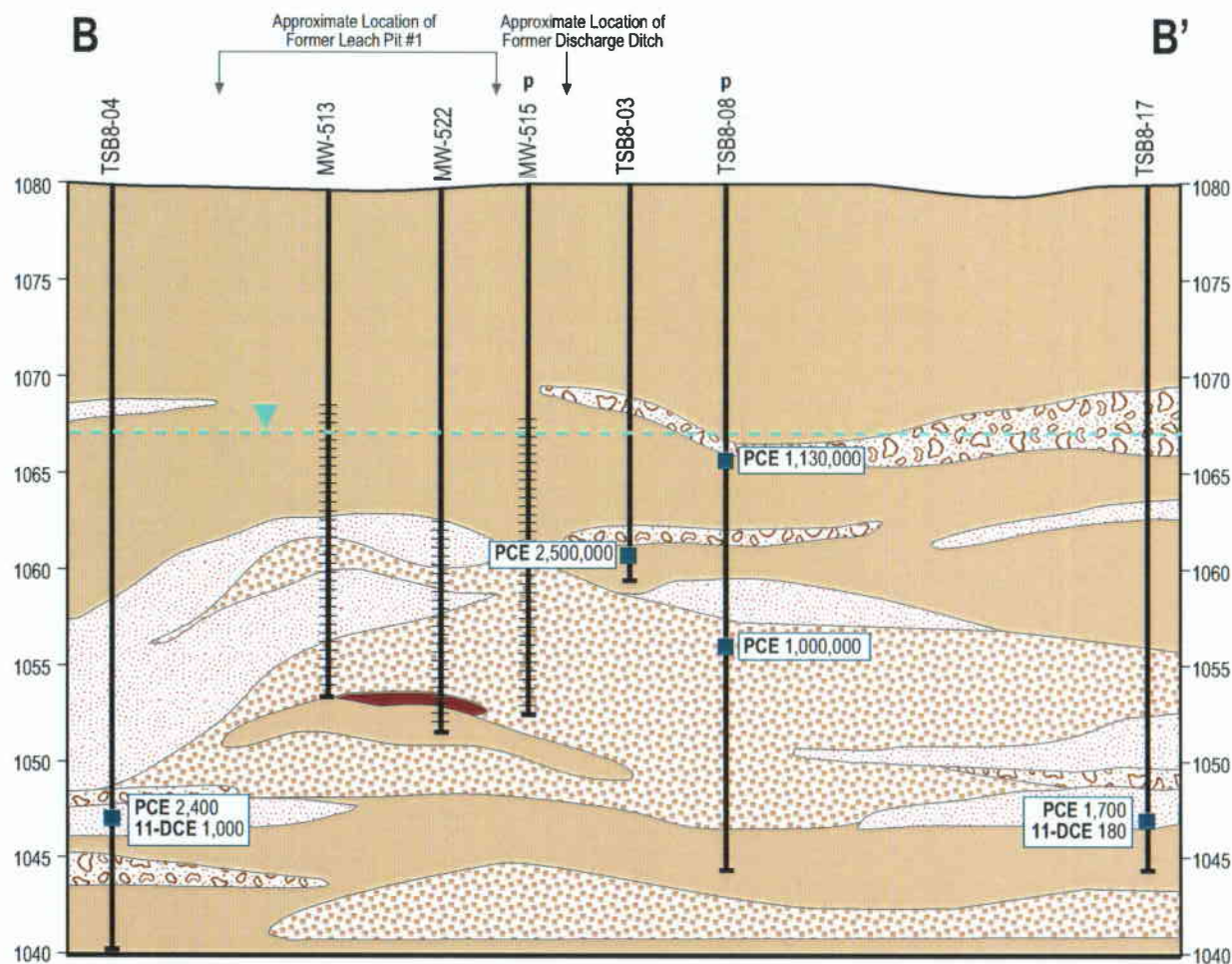


Figure 22. FY 2002 VOC Detections



LEGEND

- Clay with Silt, Sand, and Gravel
- Sandy Clay with Sand and Gravel Lenses
- Sand with Gravel
- Silt
- Clayey Gravel
- Sandstone

P Projected onto Cross-Section

Depth to Static Water Level (January 1998)

Soil Sample Location

SCALE

Horizontal: 1" = 30 ft
Vertical: 1" = 10 ft

NOTES

Concentrations in $\mu\text{g}/\text{kg}$

Soil samples were not collected from MW-513, 515, and 522 during installation

Facing
Northwest

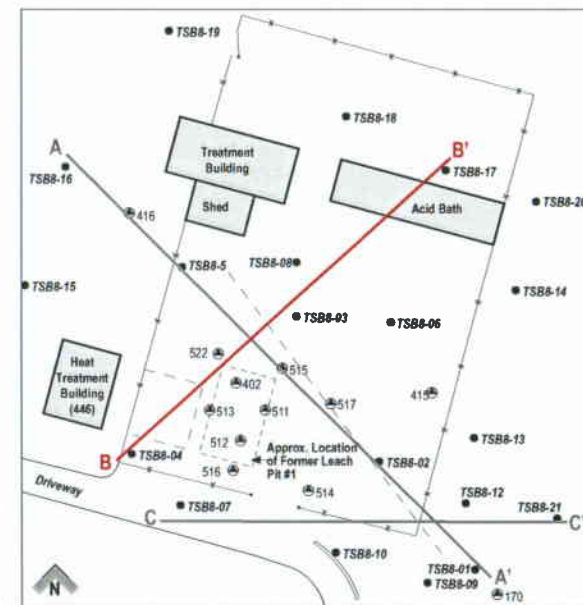
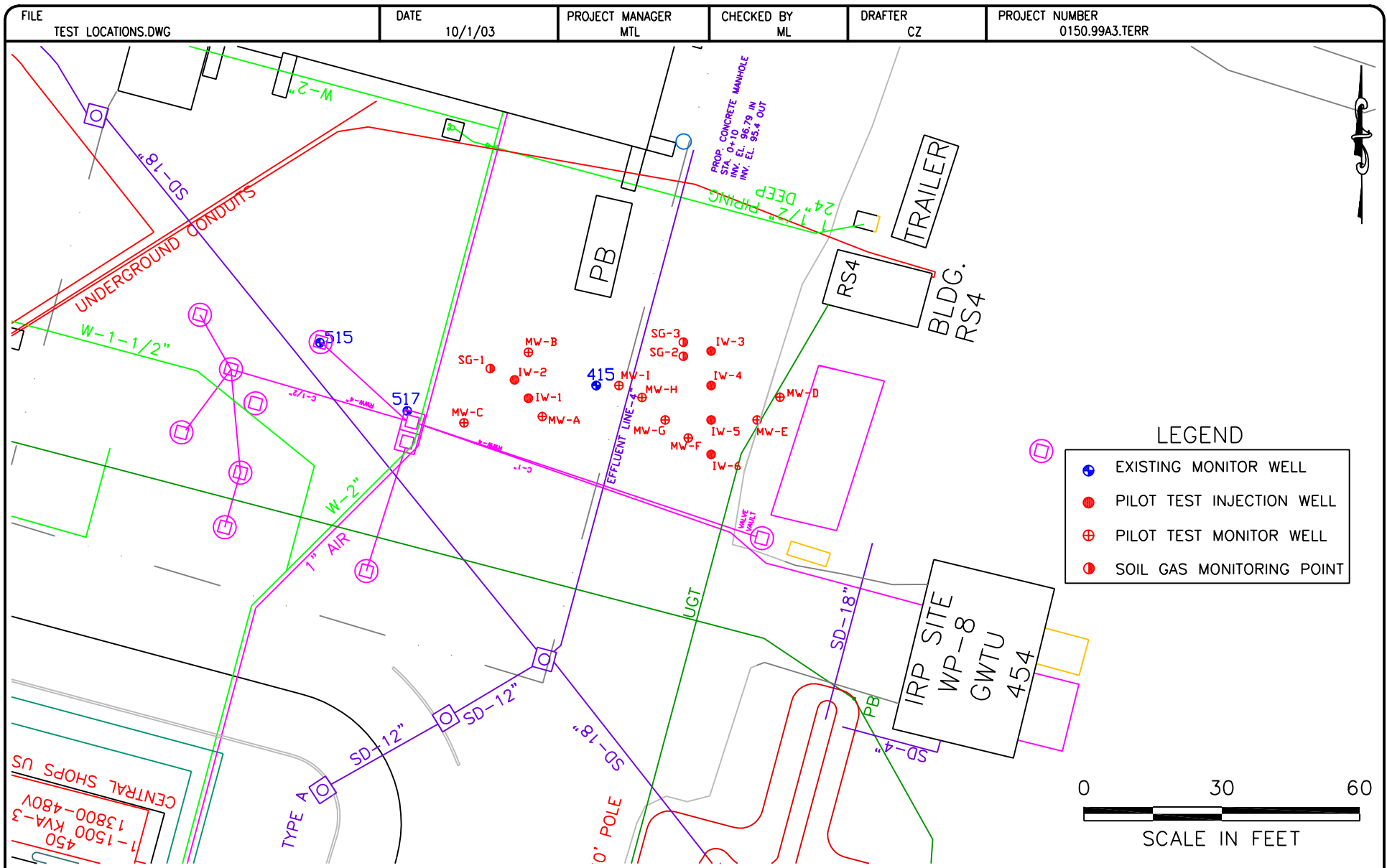
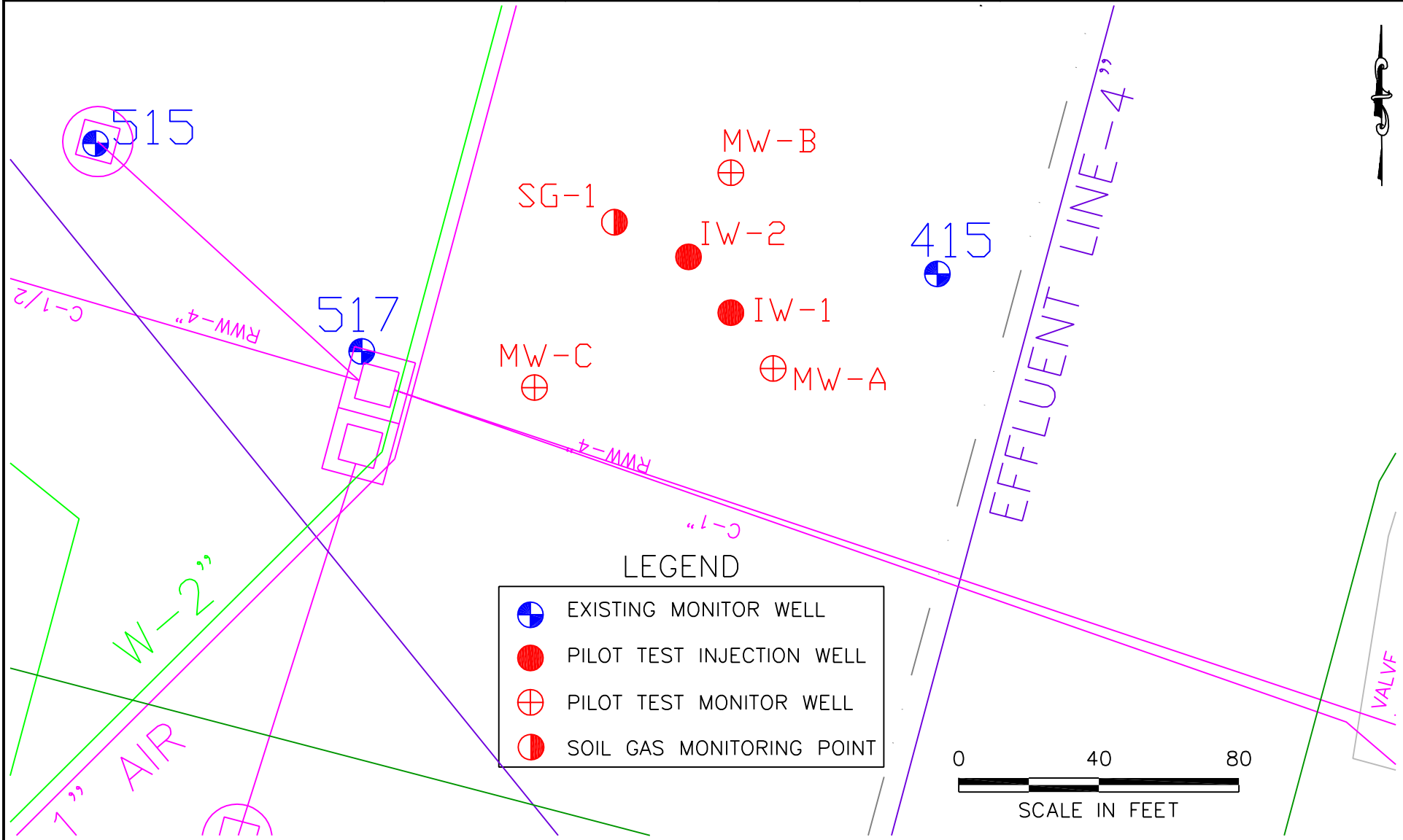


Figure 23
Soil Concentrations
Cross-Section B-B'

Arnold Air Force Base • SWMU 10 DNAPL Delineation Technical Memorandum





**CH2MHILL**

PROJECT NUMBER

131002.05.03

BORING NUMBER

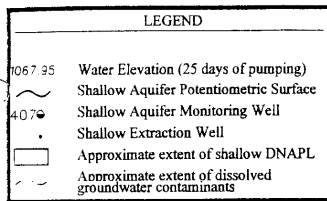
MW-415

SHEET 1 OF 1

SOIL BORING LOGPROJECT Site 3 ICM Study, Arnold Air Force BaseLOCATION Near Source AreaELEVATION _____ DRILLING CONTRACTOR Boart LongyearDRILLING METHOD AND EQUIPMENT Rotasonic 4" x 5" SystemWATER LEVEL AND DATE _____ START 1-12-97 FINISH 1-12-97 LOGGER L. Blackwelder

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (FT)	6"-6'-6" (N)	SOIL NAME, USGS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0'					No recovery- air line on rig (core barrel) plugged by ice, material soft, just pushed aside	
5'	0-5'		0	NA		
10'	5-15'		62"	NA	5-12 ft: CLAY (CL) , dark yellowish orange mottled with light gray (N6), gravelly clay lenses at 5.5 ft and 7 ft, wet, firm	PID from headspace = 289 ppm
15'					12-15 ft: CLAY (CL) , with some gravel, dark yellowish orange (10 YR 6/6), soft, wet	
20'	15-25'		108"	NA	15-16 ft: CLAY (CL) , same as 12-15 ft interval 16-18 ft: SILTY CLAY (CL) , dark yellowish orange (10 YR 6/6), moist, firm 18-20 ft: SILTY FINE SAND (SM) , very pale orange (10 YR 8/2), partially cemented from 19-20 ft, moist 20-25 ft: CLAY (CL) , dark yellowish orange (10 YR 6/6), very firm, moist	PID from headspace = 696 ppm
25'					25-30 ft: SILTY FINE SAND (SM) , very pale orange (10 YR 8/2), with coarse sand lense at 29-29.5 ft, moist	PID from headspace = 596 ppm
30'	25-35'		96"	NA	30-31 ft: SILTY CLAY (CL) , grayish orange (10 YR 7/4), moist 31-35 ft: Clayey fine to medium SAND (SM) , dark yellowish orange (10 YR 6/6), moist, soft	
35'	35-37'		20"	NA	35-37 ft: CLAY (CL) , dark yellowish orange (10 YR 6/6), moist, soft	PID from headspace = 242 ppm
40'	37-40'		43"	NA	37-40 ft: CLAY (CL) , very pale orange (10 YR 8/2) to grayish orange (10 YR 7/4) with coarse sandy clay layer at 39 ft, soft to firm, wet (firm at bottom below sandy clay layer)	PID from headspace = 696 ppm
45'					Total Depth = 40 ft	Note: Level C PPE required for well installation -13.7 ppm in breathing zone

Figure 2-6 Soil Boring Log for Well 415



Notes: Extraction wells 399, 400, 401 are not currently operating.
 Wells 407, 408, 409, and 419 not used to draw contour lines, see text for explanation.
 Extraction from wells 402, 511 through 515, 517, and 522.
 Total groundwater extraction rate of 1.72 gpm on June 2, 2000.
 Well 516 is screened in the upper part of the Shallow Aquifer.
 The other source area wells are screened in the lower part of the Shallow Aquifer.

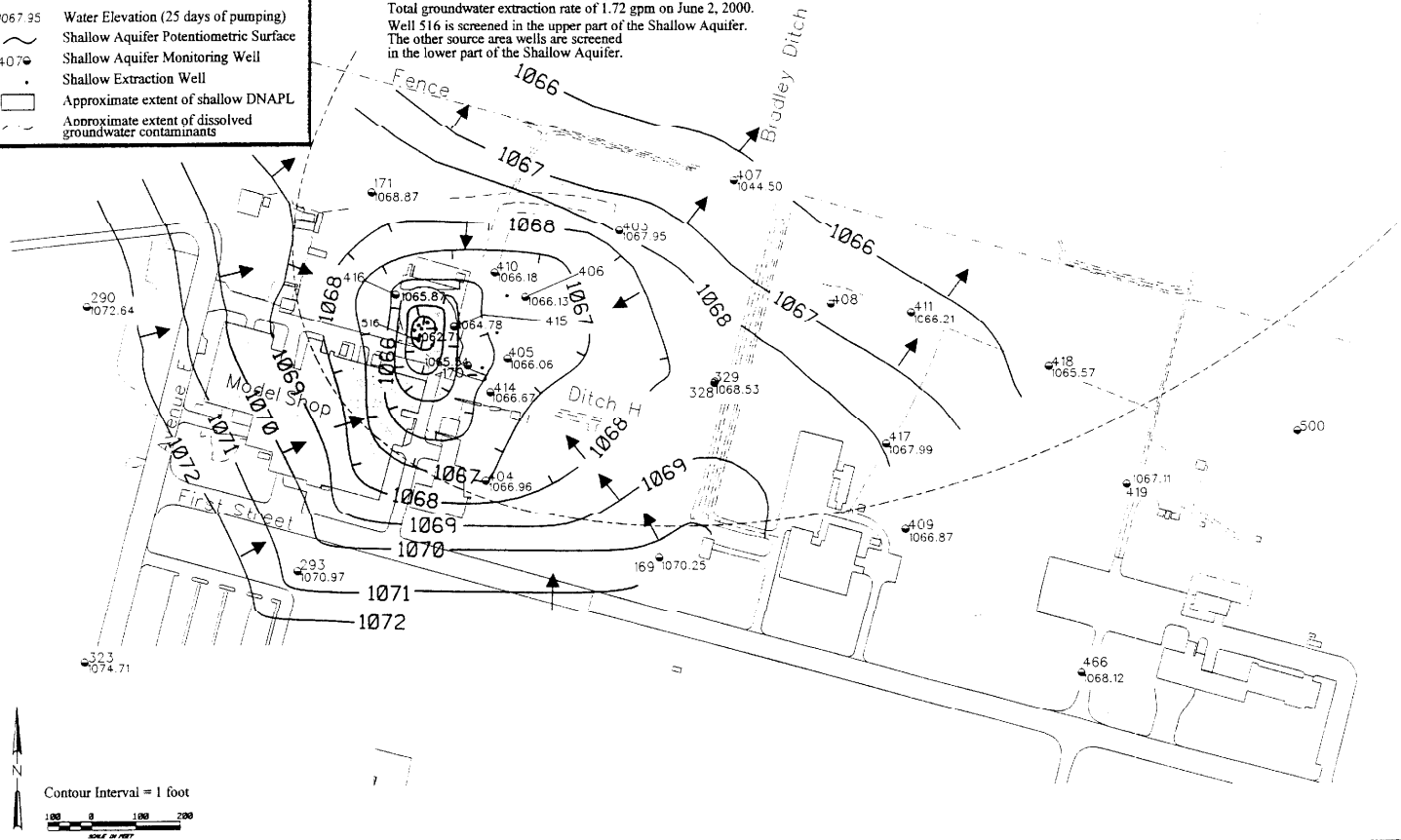


Figure 13. Pumped-Condition Shallow Groundwater Table Map (June 2, 2000: 25 Days of Pumping)

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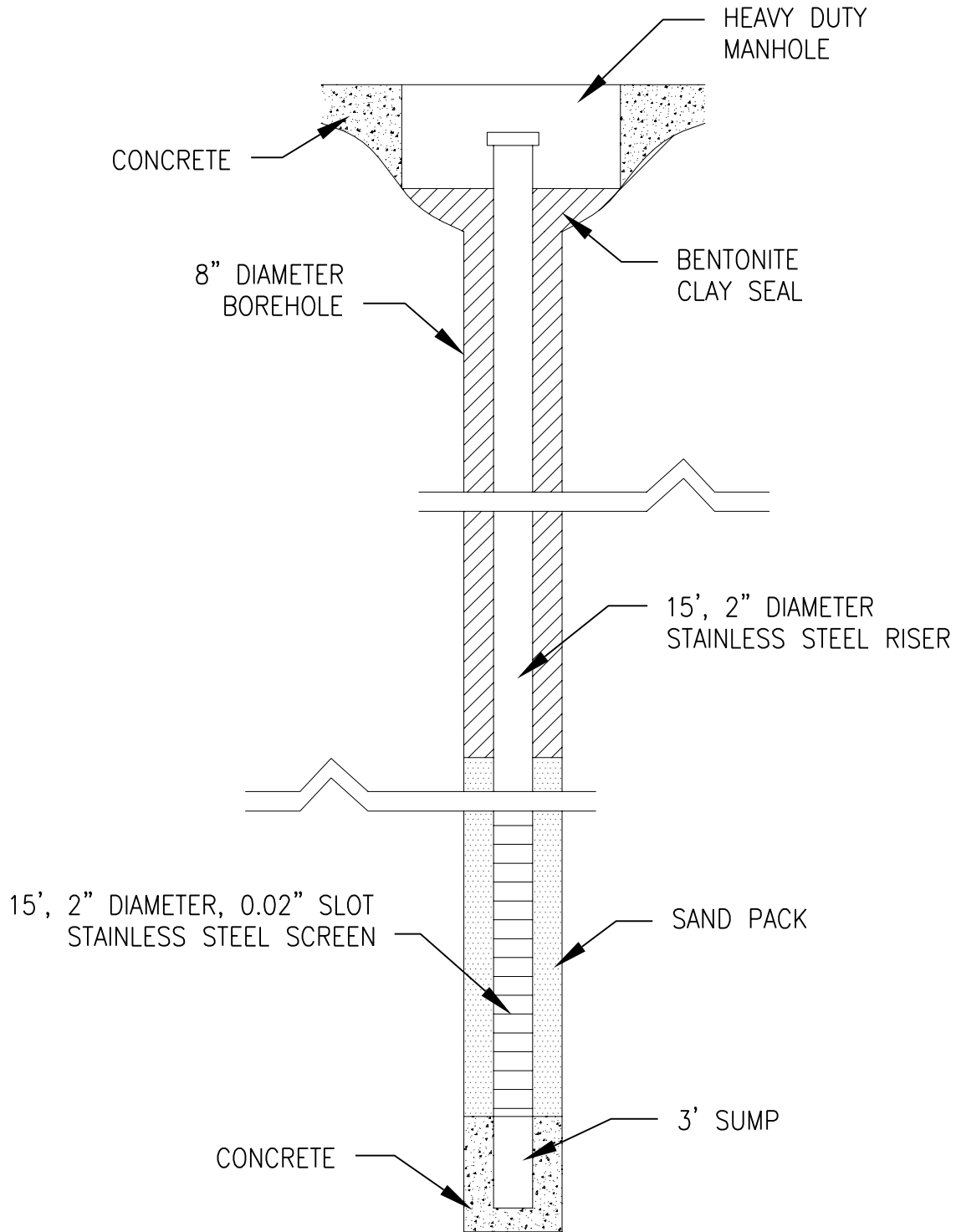
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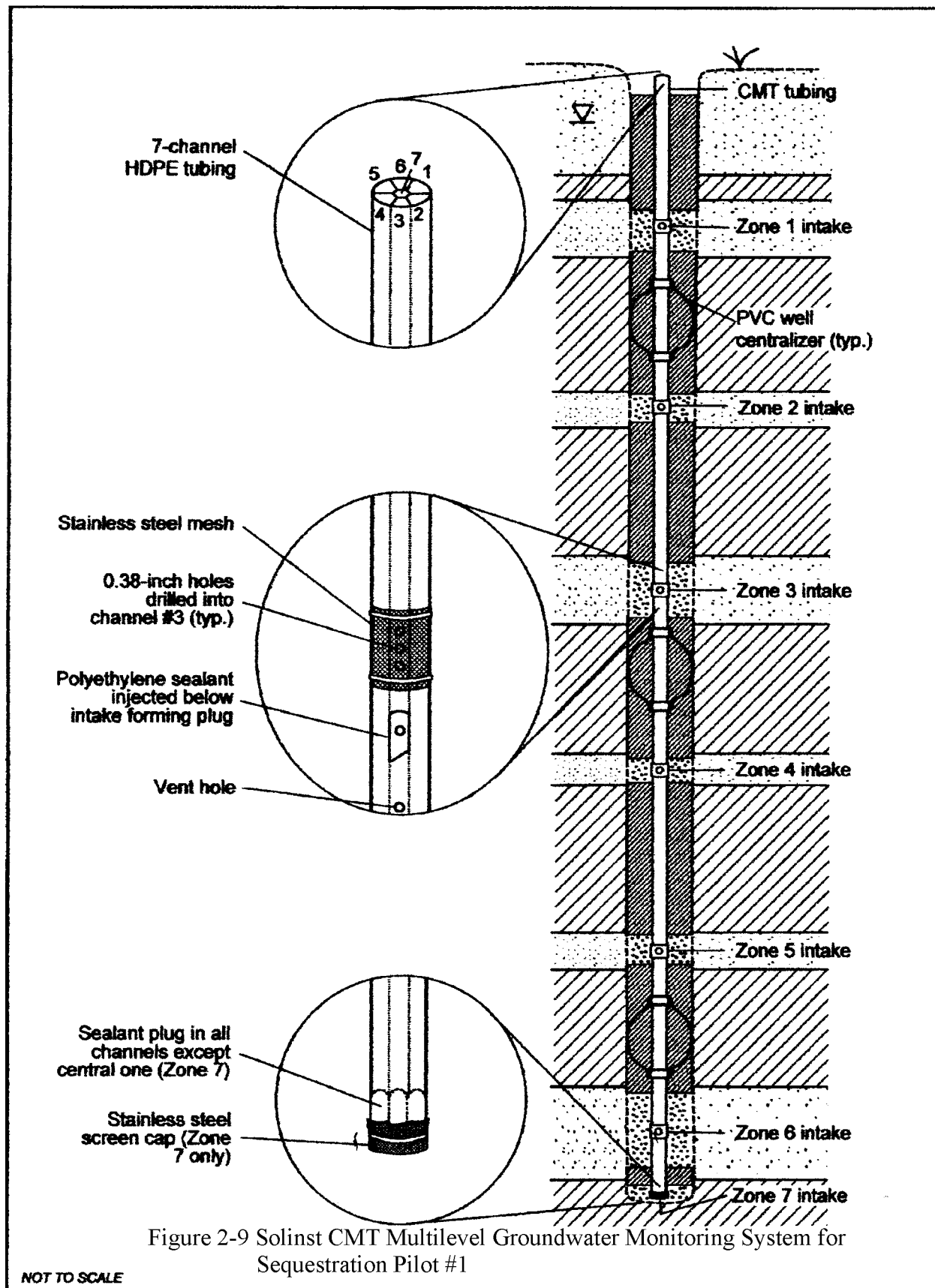
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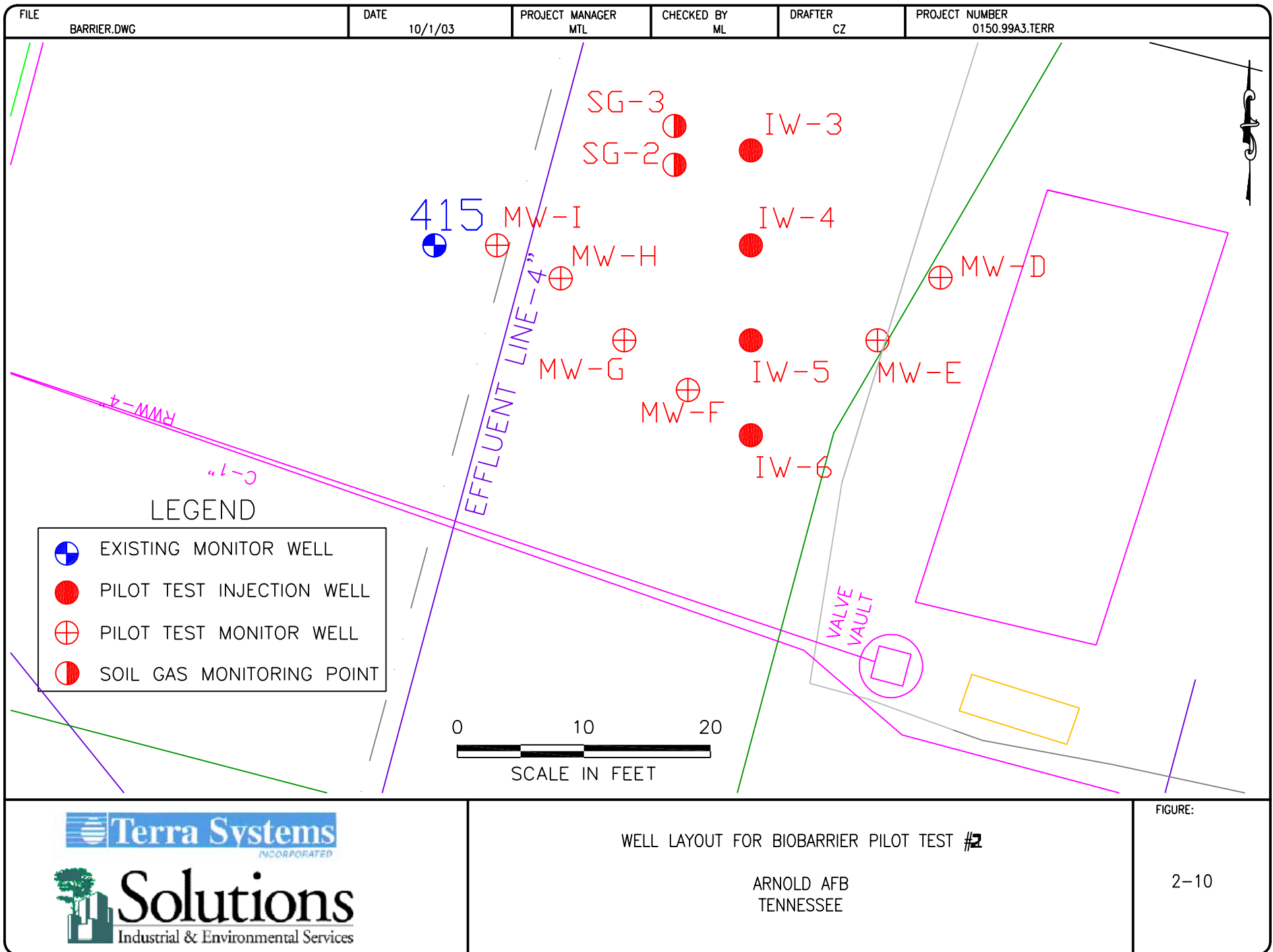
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10/1/03

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NOT TO SCALE





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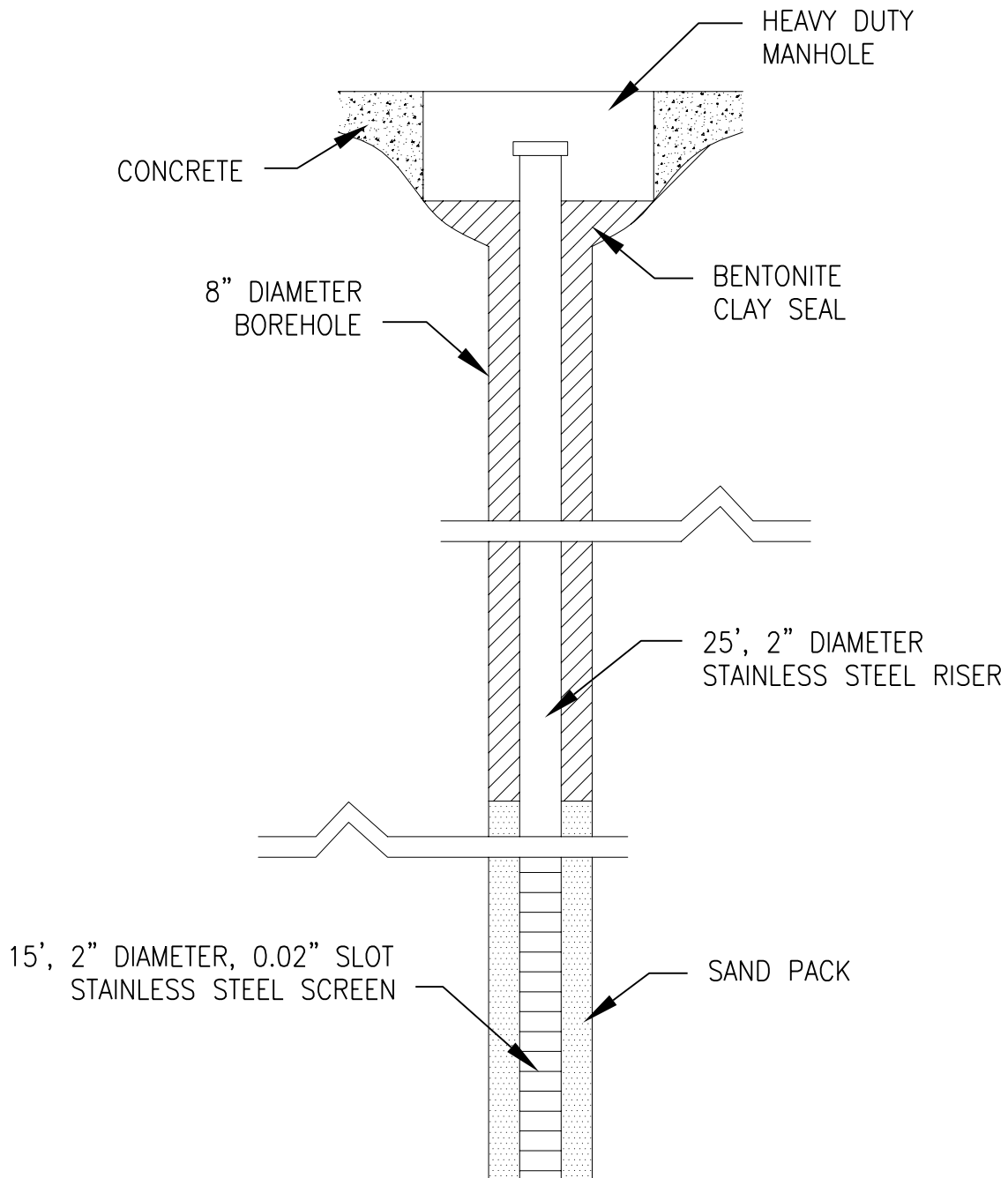
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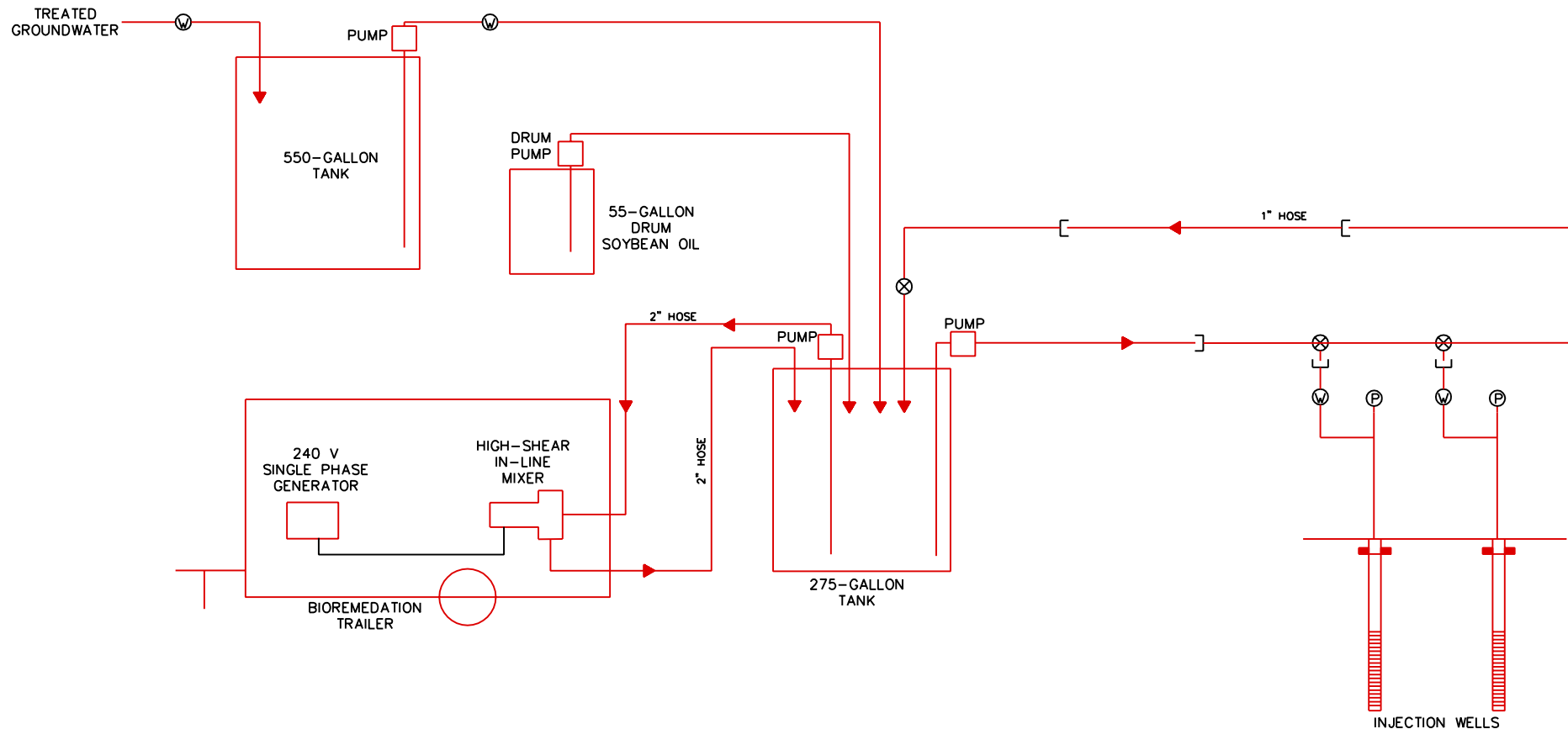
PROJECT MANAGER
MTL

DATE
9/23/03

FILE
WELL_BARRIER.DWG



NOT TO SCALE



NOTES:

1. PREPARE EMULSION WITH 160 GALLONS GROUNDWATER, 5.5 GALLONS PREMIXED SURFACTANT, 55 GALLONS SOYBEAN OIL, SODIUM BROMIDE, SODIUM BICARBONATE, AND SODIUM LACTATE.
2. RUN EMULSION THROUGH SHEAR MIXER 10 TIMES. TEST STABILITY.
3. INJECT 55 GALLONS EMULSION PER WELL.
4. CHASE WITH 1,355 GALLONS OF GROUNDWATER WITH 100 MG/L BROMIDE PER WELL.

LEGEND

- | | |
|-----|------------------|
| ⊗ | PRESSURE GAUGE |
| ⊕ | WATER METER |
| ⊗ | VALVE |
| [] | QUICK CONNECTION |



PROCESS FLOW DIAGRAM FOR PREPARATION
AND INJECTION OF SOYBEAN OIL EMULSION

ARNOLD AFB
TENNESSEE

FIGURE:

2-12

APPENDIX I

PRODUCT SHEETS AND MSDS

MATERIAL SAFETY DATA SHEET

LAMBENT TECHNOLOGIES CORP.

7247 North Central Park Avenue
Skokie, IL 60076
(847) 675-3950

CHEM-TEL EMERGENCY RESPONSE**TOLL FREE NUMBER:** (800) 255-3924**INTERNATIONAL CALLS:** COLLECT (813) 248-0585

1. PRODUCT IDENTIFICATION

Product Name: **OLEOCAL[®] IVO-114**

Synonym: Soybean Oil, RBD

2. COMPOSITION / INFORMATION ON INGREDIENTS

	CAS Number	Weight %	ACGIH TLV	OSHA PEL
Soybean Oil	8001-22-7	100	Not est.	Not est.

3. HAZARDS IDENTIFICATION

Potential Health Effects

INHALATION: Negligible unless heated to produce vapors. Vapors or finely misted materials may irritate the mucous membranes and cause irritation, dizziness, and nausea. Remove to fresh air.

EYE CONTACT: May cause irritation. Irrigate eye with water for at least 15 to 20 minutes. Seek medical attention if symptoms persist.

SKIN CONTACT: Prolonged or repeated contact is not likely to cause significant skin irritation. Material is sometimes encountered at elevated temperatures. Thermal burns are possible.

INGESTION: No hazards anticipated from ingestion incidental to industrial exposure.

4. FIRST AID MEASURES

EYES: Irrigate eyes with a heavy stream of water for at least 15 to 20 minutes.

SKIN: Wash exposed areas of the body with soap and water.

INHALATION: Remove from area of exposure, seek medical attention if symptoms persist.

INGESTION: Give one or two glasses of water to drink. If gastro-intestinal symptoms develop, consult medical personnel. (Never give anything by mouth to an unconscious person.)

5. FIRE FIGHTING MEASURES

FLASH POINT: > 200°C (>392°F)

FLASH POINT METHOD USED: Pensky Martin Closed Cup (PMCC)

FLAMMABILITY LIMITS: None known

EXTINGUISHING MEDIA: Dry chemical, foam, halon, CO₂, water spray (fog). Water stream may splash burning liquid and spread fire.

SPECIAL FIRE FIGHTING PROCEDURES: Use water spray to cool drums exposed to fire.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Firefighters should use self-contained breathing apparatus to avoid exposure to smoke and vapor.

Exercise care when disposing of rags contaminated with the product. For additional information on oily rag fires, contact your local Fire Department or Lambent Customer Service.

6. ACCIDENTAL RELEASE MEASURES

SPILL CLEAN-UP PROCEDURES: Remove sources of ignition, contain spill to smallest area possible. Stop leak if possible. Pick up small spills with absorbent materials such as paper towels, "Oil Dry", sand or dirt. Recover large spills for salvage or disposal. Wash hard surfaces with safety solvent or detergent to remove remaining oil film. Greasy nature will result in a slippery surface.

7. HANDLING AND STORAGE

Store OLEOCAL IVO-114 in closed containers between 50°F (10°C) and 120°F (49°C). Keep away from oxidizing agents, excessive heat, and ignition sources. Store and use in well ventilated areas. Do not store or use near heat, spark, or flame; store out of sun. Do not puncture, drag, or slide this container. Drum is not a pressure vessel; never use pressure to empty.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

RESPIRATORY PROTECTION: If vapors or mists are generated, wear a NIOSH approved organic vapor/mist respirator.

PROTECTIVE CLOTHING: Safety glasses, goggles, or face shield recommended to protect eyes from mists or splashing. PVC coated gloves recommended to prevent skin contact.

OTHER PROTECTIVE MEASURES: Employees must practice good personal hygiene, washing exposed areas of skin several times daily and laundering contaminated clothing before re-use.

9. PHYSICAL AND CHEMICAL PROPERTIES

Boiling Point, 760mm Hg: > 200°C (392°F)

Specific Gravity, (H₂O=1): 0.92

Evaporation Rate, (Butyl Acetate=1): < 1

Solubility in Water, % by Volume: Insoluble

Appearance and Odor: Light amber liquid with faint fatty odor

Vapor Pressure, mm Hg: < 1

Vapor Density, (Air=1): > 1

Volatiles, % by Volume: Negligible

10. STABILITY AND REACTIVITY

GENERAL: This product is stable and hazardous polymerization will not occur.

INCOMPATIBLE MATERIALS AND CONDITIONS TO AVOID: Strong oxidizing agents

HAZARDOUS DECOMPOSITION PRODUCTS: Combustion produces carbon monoxide, carbon dioxide along with thick smoke.

11. DISPOSAL CONSIDERATIONS

Waste may be disposed of by a licensed waste disposal company. Contaminated absorbent material may be disposed of in an approved land fill. Follow local, state and federal disposal regulations.

12. TRANSPORT INFORMATION

UN HAZARD CLASS: Not Applicable

DOT Transportation Data (49 CFR 172.101): Not Applicable

NMFC (National Motor Freight Classification):

PROPER SHIPPING NAME: Oils, other than petroleum, Soybean

IDENTIFICATION NUMBER: 145100

SHIPPING CLASSIFICATION: 65

International transportation

Harmonized Tariff, Schedule B: 1507.90.4050, Soybean Oil, fully refined, bleached or deodorized.

13. REGULATORY INFORMATION

OSHA STATUS: This product is not hazardous under the criteria of the Federal OSHA Hazard Communication Standard 29 CFR 1910.1200. However, thermal processing and decomposition fumes from this product may be hazardous as noted in Section 10.

TSCA STATUS: The components of this product are listed on TSCA.

CERCLA (Comprehensive Response Compensation, and Liability Act): Reportable quantity (RQ): Not established.

SARA TITLE III (Superfund Amendments and Reauthorization Act)

Section 312 Extremely Hazardous Substances: None

Section 311/312 Hazard Categories: Non-hazardous Under Section 311/312

Section 313 Toxic Chemicals: None

RCRA STATUS: If discarded in its purchased form, this product would not be a hazardous waste either by listing or by characteristic. However, under RCRA, it is the responsibility of the product user to determine at the time of disposal, whether a material containing the product or derived from the product should be classified as a hazardous waste. (40 CFR 261.20-24)

CALIFORNIA PROPOSITION 65: The following statement is made in order to comply with the California safe Drinking Water and Toxic Enforcement Act of 1986. The product contains no chemicals known to the State of California to cause cancer or reproductive toxicity.

14. OTHER INFORMATION:

NFPA Codes: Health: 1 Fire: 1 Reactivity: 0

Revision Notes:

Reason for change: 9/16/99 Change from old MSDS to Lamber format.

Reason for change: 4/22/02 Change International emergency number

Reason for change: 10/2/02 Consistency corrections.

This information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any other process. Such information is to the best of the company's knowledge and believed accurate and reliable as of the date indicated. However, no representation, warranty or guarantee of any kind, express or implied, is made as to its accuracy, reliability or completeness and we assume no responsibility for any loss, damage or expense, direct or consequential, arising out of use. It is the user's responsibility to satisfy himself as to the suitability and completeness of such information for his own particular use.

OLEOCAL® IVO-114 Soybean Oil, RBD

Chemical Description:

OLEOCAL IVO-114 is a naturally pure soybean oil extracted from select soybeans and carefully processed to ensure a light colored oil with excellent stability.

Chemical Name:

Soybean oil

CAS Number:

8001-22-7

Lambent Technologies Corp.

7247 N. Central Park Avenue
 Skokie, IL 60076
 Phone: 847-675-3950
 800-432-7187
 Fax: 847-675-3013
 lambent@petroferm.com

www.petroferm.com

OLEOCAL is a registered trademark of Petroferm Inc.

Technical Data Sheet

Product Description and Applications

LUBRICANTS:

OLEOCAL IVO-114 is used as a base oil in the formulation of environmentally friendly lubricants including hydraulic fluids, chain and bar lubricants, marine lubricants, and greases and gear oils.

OLEOCAL IVO-114 features excellent lubricity and thermal stability, good compatibility with other base fluids and additives, a high flash point and low volatility. It is biodegradable, practically non-toxic and is produced from renewable resources.

COATINGS:

OLEOCAL IVO-114 is used as a drying oil for inks, paints and varnishes. It can be used to replace mineral oils as solvents and carriers. OLEOCAL IVO-114 is also a pigment dispersant.

Specifications

Limits

Color, Lovibond 5 1/4"	1.5R max.
FFA, % (as Oleic)	0.05 max.
Iodine Value, cg Iodine/gram	128-136

Typical Properties

Appearance at 25°C (77°F)	Clear yellow liquid
Viscosity at 25°C (77°F), cSt	55.5
Viscosity at 40°C (104°F), cSt	32.0
Viscosity at 100°C (212°F), cSt	7.7
Viscosity Index	224.1
Refractive Index at 25°C (77°F)	1.46
Smoke Point, °C (°F)	235 (455)
Flash Point, COC, °C (°F)	337 (640)
Pour Point, °C (°F)	-7 (19)
Specific Gravity at 25°C (77°F)	0.92
Density, lbs./gallon	7.6

Regulatory Approvals

TSCA - US	DSL - Canada	EINECS - Europe
AICS - Australia	ECL - Korea	SWISS - Switzerland
PICCS - Philippines		

Packaging

Standard sample size is 8 oz.
 55 gal. non-returnable drum, 420 lbs. (191 kg) net

Storage and Handling

OLEOCAL IVO-114 should be stored in closed, factory sealed containers at temperatures between 50°F (10°C) and 120°F (49°C). Product should be used within six months of date of delivery.

Please refer to the Material Safety Data Sheet (MSDS) for this product for instructions on safe and proper handling and disposal.

NON WARRANTY: The data and statements contained herein are based on our research and/or the research of others, and are believed to be accurate. No guarantee of their accuracy is made however, and unless expressly stated in a written contract, the product(s) discussed herein are sold without conditions or warranties, expressed or implied. Purchasers are advised to make their own tests to determine the suitability of this product for their particular purposes. Nothing contained herein shall be construed as a recommendation to use or as a license to operate under or to infringe on any existing patent.

MATERIAL SAFETY DATA SHEET

LAMBENT TECHNOLOGIES CORP.

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Skokie, IL 60076
(847) 675-3950

CHEM-TEL EMERGENCY RESPONSE

TOLL FREE NUMBER: (800) 255-3924

INTERNATIONAL CALLS: COLLECT (813) 248-0585

1. PRODUCT IDENTIFICATION

Product Name: **LUMISORB™ PSMO-20**
Synonym: Polysorbate 80
Annexment: Product name may also have designations of **K** (Kosher), **FG** (Food Grade) or **NF** (National Formulary) , alone or in combinations.

2. COMPOSITION / INFORMATION ON INGREDIENTS

	CAS Number	Weight %	ACGIH TLV	OSHA PEL
Sorbitan monooleate, ethoxylated	9005-65-6	97-100	Not est.	Not est.

3. HAZARDS IDENTIFICATION

Potential Health Effects

INHALATION: No evidence of adverse effects from available information.

EYE CONTACT: May cause irritation.

SKIN CONTACT: No evidence of adverse effects from available information.

INGESTION: No evidence of adverse effects from available information.

4. FIRST AID MEASURES

EYES: Irrigate eyes with a heavy stream of water for at least 15 to 20 minutes.

SKIN: Wash exposed areas of the body with soap and water.

INHALATION: Remove from area of exposure, seek medical attention if symptoms persist.

INGESTION: Give one or two glasses of water to drink. If gastro-intestinal symptoms develop, consult medical personnel. (Never give anything by mouth to an unconscious person.)

5. FIRE FIGHTING MEASURES

FLASH POINT (Method Used): > 450°F (232°C)

FLASH POINT METHOD USED: COC

FLAMMABILITY LIMITS: None known

EXTINGUISHING MEDIA: Dry chemical, foam, halon, CO₂, water spray (fog). Water stream may splash burning liquid and spread fire.

SPECIAL FIRE FIGHTING PROCEDURES: Use water spray to cool drums exposed to fire.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Firefighters should use self-contained breathing apparatus to avoid exposure to smoke and vapor.

6. ACCIDENTAL RELEASE MEASURES

SPILL CLEAN-UP PROCEDURES: Remove sources of ignition, contain spill to smallest area possible. Stop leak if possible. Pick up small spills with absorbent materials such as paper towels, "Oil Dry", sand or dirt. Recover large spills for salvage or disposal. Wash hard surfaces with safety solvent or detergent to remove remaining oil film. Greasy nature will result in a slippery surface.

7. HANDLING AND STORAGE

Store LUMISORB PSMO-20 in closed containers between 50°F (10°C) and 120°F (48.8°C). Keep away from oxidizing agents, excessive heat, and ignition sources. Store and use in well ventilated areas. Do not store or use near heat, spark, or flame; store out of sun. Do not puncture, drag, or slide this container. Drum is not a pressure vessel; never use pressure to empty.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

RESPIRATORY PROTECTION: If vapors or mists are generated, wear a NIOSH approved organic vapor/mist respirator.

PROTECTIVE CLOTHING: Safety glasses, goggles, or face shield recommended to protect eyes from mists or splashing. PVC coated gloves recommended to prevent skin contact.

OTHER PROTECTIVE MEASURES: Employees must practice good personal hygiene, washing exposed areas of skin several times daily and laundering contaminated clothing before re-use.

9. PHYSICAL AND CHEMICAL PROPERTIES

Boiling Point, 760mm Hg:	> 100°C (212°F)
Specific Gravity, (H ₂ O=1):	1.07
Vapor Pressure, mm Hg:	< 1
Vapor Density, (Air=1):	> 1
Volatiles, % by Volume:	0-3% (water)
Evaporation Rate, (Butyl Acetate=1):	< 1
Solubility in Water, % by Volume:	Soluble
Appearance and Odor:	Yellow liquid with a bland odor

10. STABILITY AND REACTIVITY

GENERAL: This product is stable and hazardous polymerization will not occur.

INCOMPATIBLE MATERIALS AND CONDITIONS TO AVOID: Strong oxidizing agents

HAZARDOUS DECOMPOSITION PRODUCTS: Combustion produces carbon monoxide, carbon dioxide along with thick smoke.

11. DISPOSAL CONSIDERATIONS

Waste may be disposed of by a licensed waste disposal company. Contaminated absorbent material may be disposed of in an approved land fill. Follow local, state and federal disposal regulations.

12. TRANSPORT INFORMATION

UN HAZARD CLASS: N/A

DOT Transportation Data (49 CFR 172.101): Not Applicable

NMFC (National Motor Freight Classification):

PROPER SHIPPING NAME: Washing & cleaning compound
IDENTIFICATION NUMBER: 48580
SHIPPING CLASSIFICATION: 55

International transportation
Harmonized Tariff, Schedule B: 3402.13.2020 Organic surface active agent, nonionic, other, esters and ether-
esters of polyhydric alcohols.

13. REGULATORY INFORMATION

OSHA STATUS: This product is not hazardous under the criteria of the Federal OSHA Hazard Communication Standard 29 CFR 1910.1200. However, thermal processing and decomposition fumes from this product may be hazardous as noted in Section 10.

TSCA STATUS: The components of this product are listed on TSCA.

CERCLA (Comprehensive Response Compensation, and Liability Act): Reportable quantity (RQ): Not established.

SARA TITLE III (Superfund Amendments and Reauthorization Act)
Section 312 Extremely Hazardous Substances: None
Section 311/312 Hazard Categories: Non-hazardous Under Section 311/312
Section 313 Toxic Chemicals: None

RCRA STATUS: If discarded in its purchased form, this product would not be a hazardous waste either by listing or by characteristic. However, under RCRA, it is the responsibility of the product user to determine at the time of disposal, whether a material containing the product or derived from the product should be classified as a hazardous waste. (40 CFR 261.20-24)

CALIFORNIA PROPOSITION 65: The following statement is made in order to comply with the California safe Drinking Water and Toxic Enforcement Act of 1986. The product contains no chemicals known to the State of California to cause cancer or reproductive toxicity.

14. OTHER INFORMATION:

NFPA Codes: Health: 1 Fire: 1 Reactivity: 0

Revision Notes: 4/22/02 Change International emergency number.
Revision notes: Consistency corrections , 10/17/02

This information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any other process. Such information is to the best of the company's knowledge and believed accurate and reliable as of the date indicated. However, no representation, warranty or guarantee of any kind, express or implied, is made as to its accuracy, reliability or completeness and we assume no responsibility for any loss, damage or expense, direct or consequential, arising out of use. It is the user's responsibility to satisfy himself as to the suitability and completeness of such information for his own particular use.

Technical Data Sheet

Product Description and Applications

LUMISORB™ PSMO-20 POE (20) Sorbitan Monooleate

Product Description:

LUMISORB PSMO-20 (Polysorbate 80) is an oleic acid ester of sorbitol and its mono- and dianhydrides copolymerized with approximately 20 moles of ethylene oxide.

Chemical Name:

Polyoxyethylene (20)
sorbitan monooleate

CAS Number:

9005-65-6

INCI Designation:

Polysorbate 80

LUMISORB PSMO-20 may be labeled as:

Kosher (K)
Food Grade (FG)
Food Grade Kosher (FGK)

Lambent Technologies Corp.

7247 N. Central Park Avenue
Skokie, IL 60076
Phone: 847-675-3950
800-432-7187
Fax: 847-675-3013
lambent@petroferm.com

www.petroferm.com

LUMISORB is a trademark of Petroferm Inc.

PERSONAL CARE:

Ethoxylated sorbitan esters are known for their low toxicity and lack of skin irritation characteristics. LUMISORB PSMO-20 is recommended as a water-in-oil emulsifier for lotions, creams and solid personal care formulations. It is a general purpose emulsifier for oils, solvents and waxes.

FOOD & FOOD PROCESSING:

LUMISORB PSMO-20 is an emulsifier and multi-purpose additive for use in food products as described below:

- Emulsifier in ice cream, frozen custard, ice milk, fruit sherbet, oils and fats, dietary foods, shortenings and whipped top pings as described in 21 CFR 172.840
- Solubilizer in vitamin preparations, dill oil and pickles
- Surfactant in salt manufacturing and barbeque sauce
- Wetting agent in poultry defeathering
- Dispersant in gelatins
- Defoamer in yeast and cheese manufacturing
- Synthetic flavor adjuvant as described in 21 CFR 172.515
- Defoaming agent in food processing as described in 21 CFR 173.340

LUMISORB PSMO-20 may also be used as a processing additive in the manufacture of food packaging materials as described in 21 CFR 175.105, 175.300, 176.180 and 178.3400.

LUMISORB PSMO-20 may be used as an emulsifier in milk replacer formulations for calves as described in 21 CFR 573.860.

LUMISORB PSMO-20 conforms to 21 CFR 172.840 and meets the requirements of the *Food Chemicals Codex*, 3rd Ed., pg. 236 (1993).

OTHER APPLICATIONS:

LUMISORB PSMO-20 is an excellent general purpose emulsifier and wetting agent. LUMISORB PSMO-20 is suitable for emulsifying petroleum oils, fats, solvents and waxes in water. It may also be used in lubricants, degreasers and dry cleaning compounds. It is low foaming and is compatible with many anionic and cationic surfactants. It is especially effective when used with sorbitan esters, such as LUMISORB SMO (sorbitan monooleate).

LUMISORB PSMO-20 may perform functions as described below when used in formulations:

Antistatic Agent	Corrosion Inhibitor
Defoamer	Opacifier
Solubilizer	Stabilizer
Thickener	

NON WARRANTY: The data and statements contained herein are based on our research and/or the research of others, and are believed to be accurate. No guarantee of their accuracy is made however, and unless expressly stated in a written contract, the product(s) discussed herein are sold without conditions or warranties, expressed or implied. Purchasers are advised to make their own tests to determine the suitability of this product for their particular purposes. Nothing contained herein shall be construed as a recommendation to use or as a license to operate under or to infringe on any existing patent.

Specifications

Limits

Appearance at 25°C (77°F)	Clear liquid
Acid Value, mg KOH/gram	2.0 max.
Saponification Value, mg KOH/gram	45-55
Hydroxyl Value, mg KOH/gram	65-80
Moisture, %	3.0 max.

LUMISORB™ PSMO-20 POE (20) Sorbitan Monooleate

Typical Properties

Color, Gardner	10
pH, 5% aqueous	7
Viscosity at 25°C (77°F), cps	400
HLB	15
Flash Point, COC, °C (°F)	278 (532)
Pour Point, °C (°F)	-12 (10)
Density, lbs./gallon	9.0

LUMISORB PSMO-20 is soluble in water, alcohol, vegetable oils, ethyl acetate, methanol and toluene. It forms a gel at 60% in water and is insoluble in mineral oils.

Regulatory Approvals

TSCA - US
DSL - Canada
AICS - Australia
ECL - Korea
SWISS - Switzerland
PICCS - Philippines

Packaging

Standard sample size is 8 oz.
5 gal. pail, 44 lbs. (20 kg) net
55 gal. non-returnable drum, 450 lbs. (204.1 kg) net
Bulk

Storage and Handling

LUMISORB PSMO-20 should be stored in closed, factory sealed containers at temperatures between 50°F (10°C) and 120°F (49°C). Product should be used within one year of date of delivery.

Please refer to the Material Safety Data Sheet (MSDS) for this product for instructions on safe and proper handling and disposal.



MATERIAL SAFETY DATA SHEET

LAMBENT TECHNOLOGIES CORP.

7247 North Central Park Avenue
Skokie, IL 60076
(847) 675-3950

CHEM-TEL EMERGENCY RESPONSE

TOLL FREE NUMBER: (800) 255-3924

INTERNATIONAL CALLS: COLLECT (813) 248-0585

1. PRODUCT IDENTIFICATION

Product Name: **LUMULSE? GMO**
Synonym: Glycerol monooleate

2. COMPOSITION / INFORMATION ON INGREDIENTS

	CAS Number	Weight %	ACGIH TLV	OSHA PEL
Monoglyceride	37220-82-9		Not est.	Not est.

3. HAZARDS IDENTIFICATION

Potential Health Effects

INHALATION: Negligible unless heated to produce vapors. Vapors or finely misted materials may irritate the mucous membranes and cause irritation, dizziness, and nausea. Remove to fresh air.

EYE CONTACT: May cause irritation. Irrigate eye with water for at least 15 to 20 minutes. Seek medical attention if symptoms persist.

SKIN CONTACT: Prolonged or repeated contact is not likely to cause significant skin irritation. Material is sometimes encountered at elevated temperatures. Thermal burns are possible.

INGESTION: No hazards anticipated from ingestion incidental to industrial exposure.

4. FIRST AID MEASURES

EYES: Irrigate eyes with a heavy stream of water for at least 15 to 20 minutes.

SKIN: Wash exposed areas of the body with soap and water.

INHALATION: Remove from area of exposure, seek medical attention if symptoms persist.

INGESTION: Give one or two glasses of water to drink. If gastro-intestinal symptoms develop, consult medical personnel. (Never give anything by mouth to an unconscious person.)

5. FIRE FIGHTING MEASURES

FLASH POINT (Method Used): > 175°C (COC)

FLAMMABILITY LIMITS: None known

EXTINGUISHING MEDIA: Dry chemical, foam, halon, CO₂, water spray (fog). Water stream may splash burning liquid and spread fire.

SPECIAL FIRE FIGHTING PROCEDURES: Use water spray to cool drums exposed to fire.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Firefighters should use self-contained breathing apparatus to avoid exposure to smoke and vapor.

6. ACCIDENTAL RELEASE MEASURES

SPILL CLEAN-UP PROCEDURES: Remove sources of ignition, contain spill to smallest area possible. Stop leak if possible. Pick up small spills with absorbent materials such as paper towels, "Oil Dry", sand or dirt. Recover large spills for salvage or disposal. Wash hard surfaces with safety solvent or detergent to remove remaining oil film. Greasy nature will result in a slippery surface.

7. HANDLING AND STORAGE

Store in closed containers between 50°F and 120°F. Keep away from oxidizing agents, excessive heat, and ignition sources. Store and use in well ventilated areas. Do not store or use near heat, spark, or flame; store out of sun. Do not puncture, drag, or slide this container. Drum is not a pressure vessel; never use pressure to empty.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

RESPIRATORY PROTECTION: If vapors or mists are generated, wear a NIOSH approved organic vapor/mist respirator.

PROTECTIVE CLOTHING: Safety glasses, goggles, or face shield recommended to protect eyes from mists or splashing. PVC coated gloves recommended to prevent skin contact.

OTHER PROTECTIVE MEASURES: Employees must practice good personal hygiene, washing exposed areas of skin several times daily and laundering contaminated clothing before re-use.

9. PHYSICAL AND CHEMICAL PROPERTIES

Boiling Point, 760mm Hg:	> 200°C
Specific Gravity, (H ₂ O=1):	0.96
Vapor Pressure, mm Hg:	< 1
Vapor Density, (Air=1):	> 1
Volatiles, % by Volume:	Negligible
Evaporation Rate, (Butyl Acetate=1):	< 1
Solubility in Water, % by Volume:	< 1%
Appearance and Odor:	Opaque liquid with a bland odor

10. STABILITY AND REACTIVITY

GENERAL: This product is stable and hazardous polymerization will not occur.

INCOMPATIBLE MATERIALS AND CONDITIONS TO AVOID: Strong oxidizing agents

HAZARDOUS DECOMPOSITION PRODUCTS: Combustion produces carbon monoxide, carbon dioxide along with thick smoke.

11. DISPOSAL CONSIDERATIONS

Waste may be disposed of by a licensed waste disposal company. Contaminated absorbent material may be disposed of in an approved land fill. Follow local, state and federal disposal regulations.

12. TRANSPORT INFORMATION

UN HAZARD CLASS: N/A

13. REGULATORY INFORMATION

OSHA STATUS: This product is not hazardous under the criteria of the Federal OSHA hazard Communication Standard 29 CFR 1910.1200. However, thermal processing and decomposition fumes from this product may be hazardous as noted in Section 3.

TSCA STATUS: The component of this product is listed on the TSCA inventory.

CERCLA (Comprehensive Response Compensation, and Liability Act): Not reportable.

SARA TITLE III (Superfund Amendments and Reauthorization Act)

Section 312 Extremely Hazardous Substances: None

Section 311/312 Hazard Categories: Non-hazardous Under Section 311/312

Section 313 Toxic Chemicals: None

RCRA STATUS: If discarded in its purchased form, this product would not be a hazardous waste either by listing or by characteristic. However, under RCRA, it is the responsibility of the product user to determine at the time of disposal, whether a material containing the product or derived from the product should be classified as a hazardous waste. (40 CFR 261.20-24)

CALIFORNIA PROPOSITION 65: The following statement is made in order to comply with the California safe Drinking Water and Toxic Enforcement Act of 1986. The product contains no chemicals known to the State of California to cause cancer.

14. OTHER INFORMATION:

NFPA Codes: Health: 1 Fire: 1 Reactivity: 0

Revision Notes: 4/22/02 Change International emergency number

This information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any other process. Such information is to the best of the company's

knowledge and believed accurate and reliable as of the date indicated. However, no representation, warranty or guarantee of any kind, express or implied, is made as to its accuracy, reliability or completeness and we assume no responsibility for any loss, damage or expense, direct or consequential, arising out of use. It is the user's responsibility to satisfy himself as to the suitability and completeness of such information for his own particular use.

Sodium-L-Lactate PURASAL® S

Revision Date 08.05.2003
Ref. SD130/2003-01

1. IDENTIFICATION OF THE SUBSTANCE / PREPARATION AND THE COMPANY / UNDERTAKING

Product name	Sodium-L-Lactate, PURASAL®	
Use of the Substance	Food additive, Specialty chemical	
Supplier	PURAC biochem Arkelsedijk 46 NL-4206 AC Gorinchem The Netherlands	PURAC bioquímica Gran Vial 19 -25 08160 Montmelo-Barcelona Spain
Telephone	+31 183 695695	+34 93 568 6300
Fax	+31 183 695604	+34 93 568 3955
Emergency telephone	+31 183 695695	+34 93 568 6300 (Ext 222)
Supplier	PBR sínteses Rua Augusta, nr. 1939 - sala 122 / 123 São Paulo SP- Brazil	
Telephone	+55 11 3062 1535	
Fax	+55 11 3062 4011	
Emergency telephone	+55 11 3062 1535	

2. COMPOSITION / INFORMATION ON INGREDIENTS

Chemical name of the substance	Sodium-S-(-)-2-hydroxy propionate.
Synonyms	Sodium Lactate Sodium L-2-hydroxy propionate
EC-No.	212-762-3
CAS-No.	867-56-1

3. HAZARDS IDENTIFICATION

Most important hazards
May cause eye irritation with susceptible persons.

4. FIRST AID MEASURES

General advice
Immediate medical attention is not required.
Show this safety data sheet to the doctor in attendance.

Inhalation
Not applicable.

Skin contact
Wash off with water.

Eye contact
Rinse thoroughly with plenty of water, also under the eyelids.

Ingestion
Drink water.

Protection of first-aiders
No hazards which require special first aid measures.

Sodium-L-Lactate
PURASAL® SRevision Date 08.05.2003
Ref. SD130/2003-01**5. FIRE-FIGHTING MEASURES****Suitable extinguishing media**Water, carbon dioxide (CO₂), foam.**Extinguishing media which must not be used for safety reasons**

None.

Specific hazards

Burning produces irritant fumes.

Special protective equipment for firefighters

None.

Specific methods

Standard procedure for chemical fires.

6. ACCIDENTAL RELEASE MEASURES**Personal precautions**

Use personal protective equipment.

Environmental precautions

Prevent further leakage or spillage.

No special environmental precautions required.

Methods for cleaning up

Flush with water.

7. HANDLING AND STORAGE**Handling****Technical measures/Precautions**

No special technical protective measures required.

Safe handling advice

Handle in accordance with good industrial hygiene and safety practice.

Storage**Technical measures/Storage conditions**

Keep tightly closed in a dry place.

Avoid long storage times.

Packaging material

Steel and plastic packages.

Sodium-L-Lactate
PURASAL® SRevision Date 08.05.2003
Ref. SD130/2003-01**8. EXPOSURE CONTROLS /
PERSONAL PROTECTION****Engineering measures to reduce exposure**

Ensure adequate ventilation, especially in confined areas.

Control parameters

None.

Personal protection equipment

No special protective equipment required.

Hygiene measures

Handle in accordance with good industrial hygiene and safety practice.

**9. PHYSICAL AND CHEMICAL
PROPERTIES**

Form	aqueous solution
Colour	light yellow
Odour	slight / none
pH	6.5 - 8.5 (10 - 60% aqueous solution) @ 25°C
Boiling point/range	105°C (50% solution), 110°C (60% solution)
Decomposition temperature	> 200°C
Flash point	not applicable
Explosion limits	not applicable
Density	1320 - 1340kg/m ³ @ 20°C (60 % solution)
Solubility	Water solubility: completely soluble
Viscosity	80 - 160 mPa.s @ 20°C

**10. STABILITY AND
REACTIVITY****Stability**

Stable at normal conditions. Hazardous polymerisation does not occur.

Materials to avoid

None.

Hazardous decomposition products

Carbon oxides.

Sodium-L-Lactate
PURASAL® SRevision Date 08.05.2003
Ref. SD130/2003-01**11. TOXICOLOGICAL
INFORMATION****Acute toxicity**

Health injuries are not known or expected under normal use.
LD50/intraperitoneal/rat = 2000 mg/kg LD50/oral/rat = 2000 mg/kg.

Local effects

May cause eye irritation with susceptible persons.

Specific effects

Based on tests with L-lactic acid and its salts, there is no evidence to suggest carcinogenic nor mutagenic properties from lactic acid itself nor from the lactate portion of its metal salts.

Further information

Natural product in the body.

**12. ECOLOGICAL
INFORMATION****Mobility**

Completely soluble.

Persistence / degradability

Product is a salt of lactic acid which is readily biodegradable.

Bioaccumulation

Unlikely.

Ecotoxicity

Ecological injuries are not known or expected under normal use.
(No effect on Daphnia @ 10g/l.)

**13. DISPOSAL
CONSIDERATIONS****Waste from residues / unused products**

Can be disposed as waste water, when in compliance with local regulations.
Can be landfilled or incinerated, when in compliance with local regulations.

Contaminated packaging

Clean container with water.
Empty containers should be taken for local recycling, recovery or waste disposal.

Further information

According to the European Waste Catalogue, Waste Codes are not product specific, but application specific. Waste codes should be assigned by the user based on the application for which the product was used.

**14. TRANSPORT
INFORMATION**

Not classified as dangerous in the meaning of transport regulations.

Sodium-L-Lactate
PURASAL® SRevision Date 08.05.2003
Ref. SD130/2003-01**15. REGULATORY
INFORMATION**

The product is classified in accordance with Annex VI to Directive 67/548/EEC.

EC Food additive: E 325 USA FDA/GRAS Status.

German Water Hazard Class (WGK): 1

16. OTHER INFORMATION

Further information on the safety assessment of lactic acid and its salts can be obtained in a CFTA Report of June 6th 1997.

Additional data on the calculated ecotoxicity of lactic acid and its salts and esters can be obtained in a report entitled 'The ecotoxicity and biodegradability of lactic acid, alkyl lactate esters and lactic acid salts' by Bowmer et al. (Reference: Chemosphere 37: 1317-1333 (1998))

Indicates updated section.

SIGMA CHEMICAL CO -- YEAST EXTRACT, Y1625

MSDS Safety Information

FSC: 6505

MSDS Date: 01/01/1999

MSDS Num: CJTVD

LIIN: 00N092632

Product ID: YEAST EXTRACT, Y1625

MFN: 01

Responsible Party

Cage: 21076

Name: SIGMA CHEMICAL CO

Box: 14508

City: ST LOUIS MO 63178

Info Phone Number: 314-771-5765

Emergency Phone Number: 314-771-5765

Review Ind: Y

Published: Y

Contractor Summary

Cage: 21076

Name: SIGMA CHEMICAL COMPANY

Address: 3050 SPRUCE ST

Box: 14508

City: ST LOUIS MO 63178

Phone: 314-771-5765

Item Description Information

Ingredients

Cas: 8013-01-2

RTECS #: ZF6610000

Name: YEAST EXTRACT

Health Hazards Data

LD50 LC50 Mixture: SEE TOXICOLOGICAL INFORMATION.

Route Of Entry Inds - Inhalation: YES

Skin: YES

Ingestion: YES

Carcinogenicity Inds - NTP: NO

IARC: NO

OSHA: NO

Effects of Exposure: ACUTE: MAY BE HARMFUL BY INHALATION, INGESTION OR SKIN ABSORPTION. MAY CAUSE IRRITATION.

Signs And Symptions Of Overexposure: SEE HEALTH HAZARDS.

First Aid: INGESTION: WASH OUT MOUTH WITH WATER PROVIDED PERSON IS CONSCIOUS.

CALL MD. SKIN: FLUSH WITH COPIOUS AMOUNTS OF WATER FOR AT LEAST 15 MINUTES.

REMOVE CONTAMINATED CLOTHING AND SHOES. CALL MD. INHALATI ON: REMOVE TO FRESH

AIR. IF BREATHING BECOMES DIFFICULT, CALL MD. EYES: FLUSH WITH COPIOUS

AMOUNTS OF WATER FOR AT LEAST 15 MINUTES. ASSURE ADEQUATE FLUSHING BY

SEPARATING EYELIDS WITH FINGERS. CALL M D.

Handling and Disposal

Spill Release Procedures: WEAR PROTECTIVE EQUIPMENT. SWEEP UP, PLACE IN A BAG

AND HOLD FOR WASTE DISPOSAL. AVOID RAISING DUST. VENTILATE AREA AND WASH SPILL SITE AFTER MATERIAL PICKUP IS COMPLETE.

Waste Disposal Methods: DISSOLVE OR MIX THE MATERIAL WITH A COMBUSTIBLE SOLVENT AND BURN IN A CHEMICAL INCINERATOR EQUIPPED WITH AN AFTERBURNER AND SCRUBBER. OBSERVE ALL FEDERAL, STATE AND LOCAL ENVIRONMENTAL REGULATIONS.

Handling And Storage Precautions: STORE IN A COOL, DRY PLACE.

Fire and Explosion Hazard Information

Extinguishing Media: WATER SPRAY, CARBON DIOXIDE, DRY CHEMICAL POWDER OR APPROPRIATE FOAM.

Fire Fighting Procedures: USE NIOSH APPROVED SCBA AND FULL PROTECTIVE EQUIPMENT (FP N).

Control Measures

Respiratory Protection: WEAR APPROPRIATE NIOSH APPROVED RESPIRATOR.

Ventilation: MECHANICAL EXHAUST.

Protective Gloves: CHEMICAL-RESISTANT GLOVES.

Eye Protection: ANSI APPROVED CHEMICAL WORKERS GOGGLES (FP N).

Other Protective Equipment: ANSI APPROVED EYE WASH & DELUGE SHOWER (FP N). WEAR OTHER PROTECTIVE CLOTHING.

Supplemental Safety and Health: MFR'S INFORMATION OF INGREDIENTS: EC NO: 232-387-9.

Physical/Chemical Properties

B.P. Text: N/P'

Appearance and Odor: SOLID.

Reactivity Data

Stability Indicator: YES

Hazardous Decomposition Products: NATURE OF DECOMPOSITION PRODUCTS NOT KNOWN.

Hazardous Polymerization Indicator: NO

Conditions To Avoid Polymerization: WILL NOT OCCUR.

Toxicological Information

Toxicological Information: THE TOXICOLOGICAL PROPERTIES HAVE NOT BEEN THOROUGHLY INVESTIGATED. TOXICITY DATA: LD50:(IPR,RAT) 4500 MG/KG; LD50:(IPR,MUS) >8 GM/KG - TOIZAG 23,295,1976. ONLY SELECTED REGISTRY OF TOXIC EFFECTS OF CHEMICAL SUBSTANCES (RTECS) DATA IS PRESENTED HERE. SEE ACTUAL ENTRY IN RTECS FOR COMPLETE INFORMATION.

Ecological Information

Ecological: DATA NOT YET AVAILABLE.

MSDS Transport Information

Transport Information: CONTACT SIGMA CHEMICAL COMPANY FOR TRANSPORTATION INFORMATION.

Regulatory Information

Federal Regulatory Information: REVIEWS, STANDARDS, AND REGULATIONS: OEL=MAK. EPA TSCA SECTION 8(B) CHEMICAL INVENTORY.

Other Information

=====

HAZCOM Label

=====

Product ID: YEAST EXTRACT, Y1625

Cage: 21076

Company Name: SIGMA CHEMICAL COMPANY

Street: 3050 SPRUCE ST

PO Box: 14508

City: ST LOUIS MO

Zipcode: 63178

Health Emergency Phone: 314-771-5765

Label Required IND: Y

Date Of Label Review: 11/24/1999

Status Code: A

Origination Code: F

Eye Protection IND: YES

Skin Protection IND: YES

Signal Word: CAUTION

Respiratory Protection IND: YES

Health Hazard: Slight

Contact Hazard: Slight

Fire Hazard: None

Reactivity Hazard: None

Hazard And Precautions: ACUTE: MAY BE HARMFUL BY INHALATION, INGESTION OR SKIN
ABSORPTION. MAY CAUSE IRRITATION. CHRONIC: NONE SPECIFIED BY MANUFACTURER
(FP N).

=====

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MSDS Number: **S3170** * * * * * *Effective Date: 11/02/01* * * * * * *Supersedes: 11/17/99*

**Material Safety Data Sheet**

From: Mallinckrodt Baker, Inc.
222 Red School Lane
Phillipsburg, NJ 08865



Mallinckrodt
CHEMICALS



24 Hour Emergency Telephone: 908-859-2151
CHEMTREC: 1-800-424-9300

National Response in Canada
CANUTEC: 613-996-6666

Outside U.S. and Canada
Chemtec: 703-527-3887

NOTE: CHEMTREC, CANUTEC and National Response Center emergency numbers to be used only in the event of chemical emergencies involving a spill, leak, fire, exposure or accident involving chemicals.

All non-emergency questions should be directed to Customer Service (1-800-582-2537) for assistance.

SODIUM BROMIDE

1. Product Identification

Synonyms: Sedoneural

CAS No.: 7647-15-6

Molecular Weight: 102.89

Chemical Formula: NaBr

Product Codes:

J.T. Baker: 3588

Mallinckrodt: 0514, 0535

2. Composition/Information on Ingredients

Ingredient	CAS No	Percent	Hazardous
Sodium Bromide	7647-15-6	100%	Yes

3. Hazards Identification

Emergency Overview

WARNING! HARMFUL IF SWALLOWED. AFFECTS CENTRAL NERVOUS SYSTEM, BRAIN AND EYES. MAY CAUSE IRRITATION TO SKIN, EYES, AND RESPIRATORY TRACT.

J.T. Baker SAF -T-DATA^(tm) Ratings (Provided here for your convenience)

Health Rating: 1 - Slight

Flammability Rating: 0 - None

Reactivity Rating: 0 - None

Contact Rating: 2 - Moderate

Lab Protective Equip: GOGGLES; LAB COAT

Storage Color Code: Orange (General Storage)

Potential Health Effects

Inhalation:

Dust may cause irritation to the respiratory tract; symptoms may include coughing and shortness of breath.

Ingestion:

May cause nausea, vomiting and abdominal pain. Ingestions are usually promptly rejected by vomiting, but sufficient absorption may occur to produce central nervous system, eye and brain effects. Symptoms may include skin rash, blurred vision and other eye effects, drowsiness, irritability, dizziness, mania, hallucinations, and coma.

Skin Contact:

Dry material may cause mild irritation. Solutions may cause irritation, redness, and pain.

Eye Contact:

May cause irritation, redness and pain.

Chronic Exposure:

Repeated or prolonged exposure by any route may cause skin rashes (bromaderma).

Repeated ingestion of small amounts may cause central nervous system depression, including depression, ataxia, psychoses, memory loss, irritability, and headache.

Aggravation of Pre-existing Conditions:

Persons suffering from debilitation, depression, alcoholism, neurological or psychological disorders may be more susceptible to the effects of this compound.

4. First Aid Measures

Inhalation:

Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Call a physician.

Ingestion:

Induce vomiting immediately as directed by medical personnel. Never give anything by mouth to an unconscious person. Call a physician.

Skin Contact:

In case of contact, immediately flush skin with plenty of water for at least 15 minutes.

Remove contaminated clothing and shoes. Wash clothing before reuse. Call a physician.

Eye Contact:

Immediately flush eyes with plenty of water for at least 15 minutes, lifting lower and upper eyelids occasionally. Get medical attention immediately.

5. Fire Fighting Measures

Fire:

Not considered to be a fire hazard.

Explosion:

Not considered to be an explosion hazard.

Fire Extinguishing Media:

Use any means suitable for extinguishing surrounding fire.

Special Information:

In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full facepiece operated in the pressure demand or other positive pressure mode.

6. Accidental Release Measures

Ventilate area of leak or spill. Wear appropriate personal protective equipment as specified in Section 8. Spills: Sweep up and containerize for reclamation or disposal. Vacuuming or wet sweeping may be used to avoid dust dispersal.

7. Handling and Storage

Keep in a tightly closed container, stored in a cool, dry, ventilated area. Protect against physical damage. Containers of this material may be hazardous when empty since they retain product residues (dust, solids); observe all warnings and precautions listed for the product.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:

None established.

Ventilation System:

A system of local and/or general exhaust is recommended to keep employee exposures as low as possible. Local exhaust ventilation is generally preferred because it can control the emissions of the contaminant at its source, preventing dispersion of it into the general work

area. Please refer to the ACGIH document, *Industrial Ventilation, A Manual of Recommended Practices*, most recent edition, for details.

Personal Respirators (NIOSH Approved):

For conditions of use where exposure to dust or mist is apparent and engineering controls are not feasible, a particulate respirator (NIOSH type N95 or better filters) may be worn. If oil particles (e.g. lubricants, cutting fluids, glycerine, etc.) are present, use a NIOSH type R or P filter. For emergencies or instances where the exposure levels are not known, use a full-face positive-pressure, air-supplied respirator. **WARNING:** Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.

Skin Protection:

Wear protective gloves and clean body-covering clothing.

Eye Protection:

Use chemical safety goggles. Maintain eye wash fountain and quick-drench facilities in work area.

9. Physical and Chemical Properties

Appearance:

White crystals, granules, or powder

Odor:

Odorless.

Solubility:

116 g/100 g water @ 50C (122F)

Specific Gravity:

3.21

pH:

No information found.

% Volatiles by volume @ 21C (70F):

0

Boiling Point:

1390C (2534F)

Melting Point:

755C (1391F)

Vapor Density (Air=1):

No information found.

Vapor Pressure (mm Hg):

No information found.

Evaporation Rate (BuAc=1):

No information found.

10. Stability and Reactivity

Stability:

Stable under ordinary conditions of use and storage. Absorbs moisture from air.

Hazardous Decomposition Products:

Oxides of the contained metal and halogen, possibly also free, or ionic halogen.

Hazardous Polymerization:

Will not occur.

Incompatibilities:

Acids, alkaloidal and heavy metal salts, oxidizers, and bromine trifluoride.

Conditions to Avoid:

Moisture and incompatibles.

11. Toxicological Information

Toxicological Data:

Sodium Bromide: Oral rat LD50: 3500 mg/kg. Investigated as a reproductive effector.

Reproductive Toxicity:

Causes reproductive system effects in laboratory animals.

-----\Cancer Lists\-----			
Ingredient	---NTP Carcinogen---		IARC Category
	Known	Anticipated	

Sodium Bromide (7647-15-6)	No	No	None

12. Ecological Information

Environmental Fate:

No information found.

Environmental Toxicity:

No information found.

13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be managed in an appropriate and approved waste disposal facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

14. Transport Information

Not regulated.

15. Regulatory Information

```

-----\Chemical Inventory Status - Part 1\-----
Ingredient                                     TSCA   EC    Japan  Australia
-----
Sodium Bromide (7647-15-6)                   Yes   Yes   Yes    Yes

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```

-----\Chemical Inventory Status - Part 2\-----
Ingredient                                     Korea  DSL   NDSL   Phil.
-----
Sodium Bromide (7647-15-6)                   Yes   Yes   No     Yes

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-----\Federal, State & International Regulations - Part 1\-----
Ingredient                                     -SARA 302-  -SARA 313-----
RQ      TPQ      List  Chemical Catg.
-----
Sodium Bromide (7647-15-6)                   No     No     No     No

```

```

-----\Federal, State & International Regulations - Part 2\-----
Ingredient                                     CERCLA  -RCRA-  -TSCA-
                                     261.33  8(d)
-----
Sodium Bromide (7647-15-6)                   No     No     No

```

Chemical Weapons Convention: No TSCA 12(b): No CDTA: No
 SARA 311/312: Acute: Yes Chronic: Yes Fire: No Pressure: No
 Reactivity: No (Pure / Solid)

Australian Hazchem Code: None allocated.

Poison Schedule: None allocated.

WHMIS:

This MSDS has been prepared according to the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all of the information required by the CPR.

16. Other Information

NFPA Ratings: Health: **2** Flammability: **0** Reactivity: **0**

Label Hazard Warning:

WARNING! HARMFUL IF SWALLOWED. AFFECTS CENTRAL NERVOUS SYSTEM, BRAIN AND EYES. MAY CAUSE IRRITATION TO SKIN, EYES, AND RESPIRATORY TRACT.

Label Precautions:

Avoid breathing dust.
 Keep container closed.
 Use with adequate ventilation.
 Avoid contact with eyes, skin and clothing.
 Wash thoroughly after handling.

Label First Aid:

If swallowed, induce vomiting immediately as directed by medical personnel. Never give anything by mouth to an unconscious person. If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. In case of contact, immediately flush eyes or skin with plenty of water for at least 15 minutes. In all cases call a physician.

Product Use:

Laboratory Reagent.

Revision Information:

MSDS Section(s) changed since last revision of document include: 8.

Disclaimer:

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Prepared by: Environmental Health & Safety

Phone Number: (314) 654-1600 (U.S.A.)

MSDS Number: **S2954** * * * * * *Effective Date: 05/16/03* * * * * * *Supersedes: 11/02/01*

MSDS**Material Safety Data Sheet**

From: Mallinckrodt Baker, Inc.
222 Red School Lane
Phillipsburg, NJ 08865



Mallinckrodt
CHEMICALS



24 Hour Emergency Telephone: 908-859-2151
CHEMTREC: 1-800-424-9300

National Response in Canada
CANUTEC: 613-996-6666

Outside U.S. and Canada
Chemtrec: 703-527-3887

NOTE: CHEMTREC, CANUTEC and National Response Center emergency numbers to be used only in the event of chemical emergencies involving a spill, leak, fire, exposure or accident involving chemicals.

All non-emergency questions should be directed to Customer Service (1-800-582-2537) for assistance.

SODIUM BICARBONATE

1. Product Identification

Synonyms: Sodium hydrogen carbonate; sodium acid carbonate; baking soda; bicarbonate of soda

CAS No.: 144-55-8

Molecular Weight: 84.01

Chemical Formula: NaHCO₃

Product Codes:

J.T. Baker: 3506, 3508, 3509, 3510

Mallinckrodt: 7285, 7396, 7397, 7412, 7749, 7903

2. Composition/Information on Ingredients

Ingredient	CAS No	Percent	Hazardous
-----	-----	-----	-----
Sodium Bicarbonate	144-55-8	99 - 100%	No

3. Hazards Identification

Emergency Overview

As part of good industrial and personal hygiene and safety procedure, avoid all unnecessary exposure to the chemical substance and ensure prompt removal from skin, eyes and clothing.

SAF-T-DATA^(tm) Ratings (Provided here for your convenience)

Health Rating: 1 - Slight
Flammability Rating: 1 - Slight
Reactivity Rating: 1 - Slight
Contact Rating: 1 - Slight
Lab Protective Equip: GOGGLES; LAB COAT
Storage Color Code: Green (General Storage)

Potential Health Effects

Inhalation:

High concentrations of dust may cause coughing and sneezing.

Ingestion:

Extremely large oral doses may cause gastrointestinal disturbances.

Skin Contact:

No adverse effects expected.

Eye Contact:

Contact may cause mild irritation, redness, and pain.

Chronic Exposure:

No information found.

Aggravation of Pre-existing Conditions:

No information found.

4. First Aid Measures

Inhalation:

Remove to fresh air. Get medical attention for any breathing difficulty.

Ingestion:

Give several glasses of water to drink to dilute. If large amounts were swallowed, get medical advice.

Skin Contact:

Not expected to require first aid measures.

Eye Contact:

Wash thoroughly with running water. Get medical advice if irritation develops.

5. Fire Fighting Measures

Fire:

Not considered to be a fire hazard.

Explosion:

Not considered to be an explosion hazard.

Fire Extinguishing Media:

Use any means suitable for extinguishing surrounding fire.

Special Information:

Use protective clothing and breathing equipment appropriate for the surrounding fire.

6. Accidental Release Measures

Ventilate area of leak or spill. Wear appropriate personal protective equipment as specified in Section 8. Spills: Sweep up and containerize for reclamation or disposal. Vacuuming or wet sweeping may be used to avoid dust dispersal. Small amounts of residue may be flushed to sewer with plenty of water.

7. Handling and Storage

Keep in a tightly closed container, stored in a cool, dry, ventilated area. Protect against physical damage. Containers of this material may be hazardous when empty since they retain product residues (dust, solids); observe all warnings and precautions listed for the product.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:

None established.

Ventilation System:

In general, dilution ventilation is a satisfactory health hazard control for this substance. However, if conditions of use create discomfort to the worker, a local exhaust system should be considered.

Personal Respirators (NIOSH Approved):

For conditions of use where exposure to dust or mist is apparent and engineering controls are not feasible, a particulate respirator (NIOSH type N95 or better filters) may be worn. If oil particles (e.g. lubricants, cutting fluids, glycerine, etc.) are present, use a NIOSH type R or P filter. For emergencies or instances where the exposure levels are not known, use a full-face positive-pressure, air-supplied respirator. **WARNING:** Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.

Skin Protection:

Wear protective gloves and clean body-covering clothing.

Eye Protection:

Use chemical safety goggles. Maintain eye wash fountain and quick-drench facilities in work area.

9. Physical and Chemical Properties

Appearance:

White crystalline powder.

Odor:

Odorless.

Solubility:

7.8g/100g water @ 18C (64F).

Density:

2.2

pH:

8.3 (0.1 molar @ 25C (77F))

% Volatiles by volume @ 21C (70F):

0

Boiling Point:

Not applicable.

Melting Point:

60C (140F)

Vapor Density (Air=1):

No information found.

Vapor Pressure (mm Hg):

No information found.

Evaporation Rate (BuAc=1):

No information found.

10. Stability and Reactivity

Stability:

Stable under ordinary conditions of use and storage.

Hazardous Decomposition Products:

Gaseous carbon dioxide.

Hazardous Polymerization:

Will not occur.

Incompatibilities:

Reacts with acids to form carbon dioxide. Dangerous reaction with monoammonium phosphate or a sodium-potassium alloy.

Conditions to Avoid:

Heat, moisture, incompatibles.

11. Toxicological Information

Investigated as a mutagen, reproductive effector. Oral rat LD50: 4220 mg/kg. Irritation

data: human,skin, 30mg/3D-I mild, rabbit,eye, 100 mg/30 S, mild.

-----\Cancer Lists\-----			
Ingredient	---NTP Carcinogen---		IARC Category
	Known	Anticipated	
Sodium Bicarbonate (144-55-8)	No	No	None

12. Ecological Information

Environmental Fate:

No information found.

Environmental Toxicity:

No information found.

13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be managed in an appropriate and approved waste disposal facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

14. Transport Information

Not regulated.

15. Regulatory Information

-----\Chemical Inventory Status - Part 1\-----				
Ingredient	TSCA	EC	Japan	Australia
Sodium Bicarbonate (144-55-8)	Yes	Yes	Yes	Yes

-----\Chemical Inventory Status - Part 2\-----				
Ingredient	Korea	--Canada--		Phil.
		DSL	NDSL	
Sodium Bicarbonate (144-55-8)	Yes	Yes	No	Yes

-----\Federal, State & International Regulations - Part 1\-----				
Ingredient	-SARA 302-		-----SARA 313-----	
	RQ	TPQ	List	Chemical Catg.

Sodium Bicarbonate (144-55-8)	No	No	No	No
-----\Federal, State & International Regulations - Part 2\-----				
Ingredient	CERCLA	-RCRA-	261.33	-TSCA-
				8(d)
Sodium Bicarbonate (144-55-8)	No	No	No	No

Chemical Weapons Convention: No TSCA 12(b): No CDTA: No
 SARA 311/312: Acute: No Chronic: No Fire: No Pressure: No
 Reactivity: No (Pure / Solid)

Australian Hazchem Code: None allocated.

Poison Schedule: None allocated.

WHMIS:

This MSDS has been prepared according to the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all of the information required by the CPR.

16. Other Information

NFPA Ratings: Health: 1 Flammability: 0 Reactivity: 0

Label Hazard Warning:

As part of good industrial and personal hygiene and safety procedure, avoid all unnecessary exposure to the chemical substance and ensure prompt removal from skin, eyes and clothing.

Label Precautions:

None.

Label First Aid:

Not applicable.

Product Use:

Laboratory Reagent.

Revision Information:

MSDS Section(s) changed since last revision of document include: 3.

Disclaimer:

Mallinckrodt Baker, Inc. provides the information contained herein in good faith but makes no representation as to its comprehensiveness or accuracy. This document is intended only as a guide to the appropriate precautionary handling of the material by a properly trained person using this product. Individuals receiving the information must exercise their independent judgment in determining its appropriateness for a particular purpose. MALLINCKRODT BAKER, INC. MAKES NO REPRESENTATIONS OR WARRANTIES, EITHER EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION ANY WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO THE INFORMATION SET FORTH HEREIN OR THE PRODUCT

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Prepared by: Environmental Health & Safety
Phone Number: (314) 654-1600 (U.S.A.)

APPENDIX II

EQUIPMENT SPECIFICATIONS



CMT Multilevel System

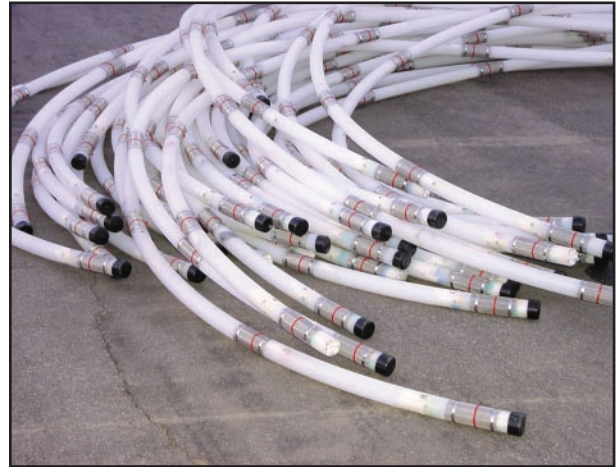
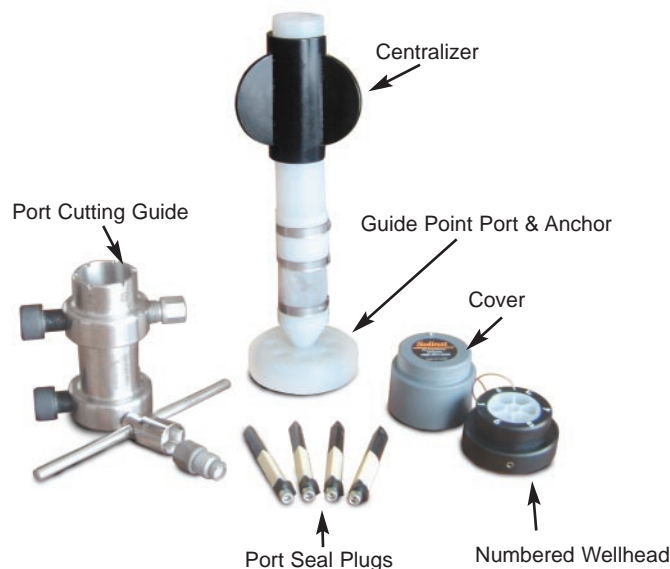
Model 403

This reliable easy to install and inexpensive multilevel system provides site assessors with a better understanding of the three-dimensional groundwater flow and distribution of contaminants. Remediation strategies can then be targeted more precisely, focusing efforts in the most effective manner.

The CMT Multilevel System makes the accurate monitoring of contaminant plumes much more affordable. It provides detailed vertical as well as horizontal data. The simple 1.7" (43 mm) OD polyethylene tube is segmented into 7 channels, allowing groundwater monitoring at up to 7 depth-discrete zones. Monitoring zones are set where needed and the single tube design allows reliable seals between zones.

Applications

- Ideal for shallow wells in high water table
- Multilevel water sampling and level monitoring in unconsolidated soils, bedrock or screened wells
- Monitoring of natural attenuation or remediation processes
- Identify vertical as well as horizontal contaminant distribution with transect monitoring
- NAPL, VOC and MTBE Monitoring
- Mass transport calculations and mass flux estimation
- Determination of the best location for reactive barrier walls



Endorsements

"We used CMT to monitor groundwater down gradient of an ORC barrier wall in a pilot study at a Superfund site....Our results showed that the CMT and packers performed as expected, isolating each sampling zone. Use of the CMT was an excellent idea."

*Brian Butler, Senior Geologist,
Harding ESE*

"Our initial assessment of the CMT system is that, it is performing as expected and we are pleased with the capability it provides..... Really great innovation, characterizes core of plume with far fewer wells."

*Fred Kintzer, Principal Geologist, Project
Manager
Parsons Engineering Science Inc.*

"On a chlorinated solvent site, it was extremely useful as a site characterization tool to better map contaminant's in 3D allowed targeting of remediation efforts."

*Tim Buscheck,
Senior Staff Hydrogeologist,
ChevronTexaco*



Numbered Wellhead

Advantages of Multilevel Systems

- Provides the most accurate 3-D assessment of a site
- Vital to understanding vertical flow of contaminants
- Allow documentation of changes in the concentration and delineation of a contaminant plume
- Low cost compared with multiple individual wells

Research has shown that contaminant plumes are often thin and highly stratified. Traditional monitoring wells, with screened intervals of 10 ft. (3 m) or more, blend the groundwater over the entire length of the screen. This can mask the true concentrations and distribution of contaminants. Multilevel wells with short screened intervals overcome this problem and offer more precise identification, better design options for treatment and ongoing monitoring.

Advantages of the CMT Multilevel

- Low cost and ease of use
- Up to 7 depth-discreet zones in a single tube
- No joints: one smooth surface for easy, effective sealing
- Locate ports and packers anywhere along the tubing
- Installations completed using alternate sand and bentonite layers are reliable and inexpensive
- Double-Acting Packers allow easy system removal
- Simple system usually customized and built on site
- The hole is not left open to allow cross contamination
- Installs quickly in large direct-push casing and bigger holes
- One 7-zone CMT System can be completed by two people in under 3 hours.
- Minimizes the risk of producing new contaminant pathways.

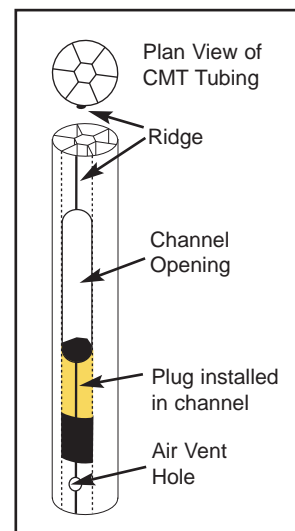


CMT Installation

Multichannel Tubing

A multilevel well that uses a continuous length of multichannel tubing has the advantage over other multilevels in that there are no joints. This significantly reduces the time and cost of installing wells and at the same time increases the reliability of the system. The CMT tubing is very simple and convenient to use, as it gives full flexibility as to where monitoring zones are located. Also a single coil of tubing can be used for a number of well installations.

The tubing has a ridge down its entire length to allow for easy identification of specific channels. Ports and packers can be assembled in the field, immediately after drilling the borehole, to reduce open hole time and potential cross-contamination between zones.



Port Configuration



Inserting a Plug



Completed Port

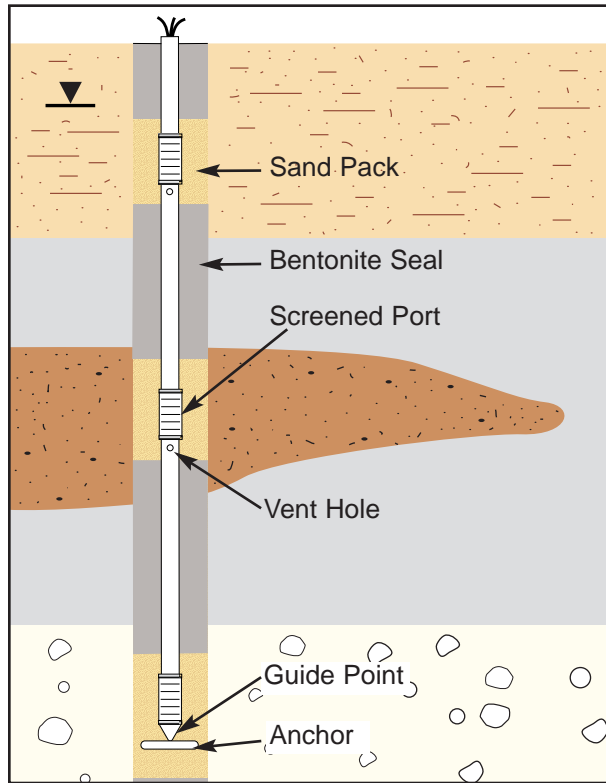
Ports

The number and location of ports may be determined in advance, or after drilling the borehole. A Port Cutting Guide is used to cut 2 holes in a vertical line into a given channel, at the specified depth for each zone to be monitored. The plastic between the holes is cut out leaving an opening suitable for inserting a plug, as illustrated above. The plug is positioned and sealed in the channel just below the channel opening.

A vent hole is also placed just below the plug to allow air to escape as the system is lowered into the borehole. This allows water from the monitoring zone to fill the channel below the zone to overcome buoyancy. A stainless steel screen is fixed in place over the port to prevent fines from entering. The screen kits come in a variety of mesh sizes, complete with clamps and plugs. Each channel is sealed at the bottom of the tubing to avoid cross contamination between monitoring zones.

Seals & Packers

The CMT tubing can be installed using standard sand and bentonite layers placed using a tremie pipe, shallow depth gravity feed, or with the Solinst Mini Sand Bentonite Injector, (Model 561M). If the application is in loose sands, direct burial can be used, allowing the sand to collapse around the tubing.



Typical CMT Installation in Overburden with Bentonite Seals and Sand Pack



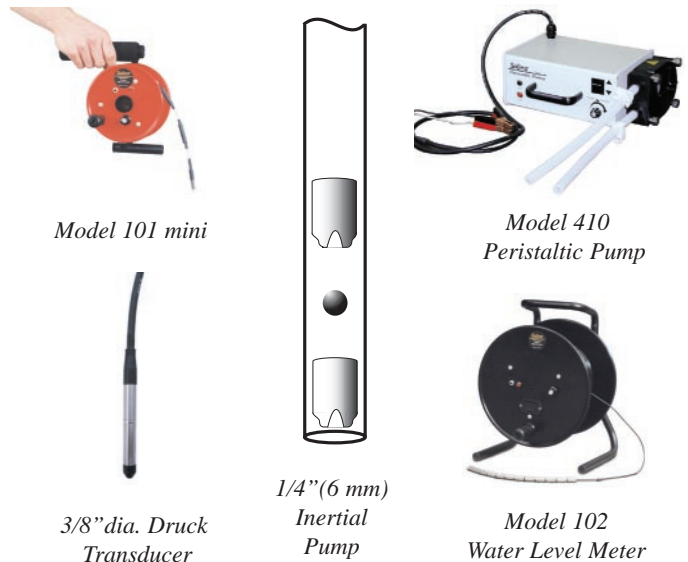
Ports and packers are placed exactly where needed prior to installation

Double-Acting Packers

Double-Acting Packers are ideal for use in situations where a CMT System is in a cased or screened well, or in a smooth rock borehole, and when removal of the system for decommissioning or reuse is important. The Double-Acting Packers have both an inner and an outer gland to seal against the CMT tubing and the borehole. The packers are hydraulically inflated allowing easy removal.

Monitoring Your CMT Multilevel

Water levels can be accurately established using the Solinst Mini 101 Water Level Meter in shallow CMT Systems. Lengths of 30ft, 65ft, 10m or 20m of the narrow 1/4" (6 mm) tape are mounted on a convenient small reel. A narrower coaxial cable Model 102 Water Level Meter may be easier for use in deeper CMT Systems. Levels can also be datalogged using a 3/8" (10 mm) diameter Druck Transducer. Sampling can be performed using the Solinst Model 410 Peristaltic Pump up to the suction lift limit of approximately 25 ft (7.5 m) or with a Mini Inertial Pump for greater depths.



CMT System Components

The tubing is available in lengths of 100ft, 200ft & 300ft (30m, 60m & 90m). The tubing coils are approximately 4ft. (1.2m) in diameter. If deeper multilevels are desired the Waterloo Multilevel System can be considered. (See Data Sheet 401). CMT tubing is laid out on the ground or plastic sheeting for the preparation of ports, and for placement of packers, when used. The 1.7" (43mm) OD CMT tubing has 7 channels. The 6 outer channels are approximately 7/16" ID (11mm) and the smaller central channel is 3/8" (9.5mm). The port screens are held in place using low profile clamps.

Double-Acting Packers are available in diameters to seal 3" and 4" (75 mm and 100 mm) wells. Centralizers can be used to help position the tubing in the borehole to ensure proper sand and bentonite distribution. The base of the system is completed with a Guide Point Port, which functions both as a point for easier installation and as a seventh port when needed. An optional anchor may be added to prevent the system from lifting during installation. The top of the CMT System is completed with a numbered wellhead that labels each channel for easy identification.

Drilling Methods and Techniques for Installing CMT Wells in Unconsolidated Aquifers

Drilling Method	Advantages	Preferred CMT Installation Technique	Comments
Sonic	Casing advance during drilling minimizes redistribution of contaminant's in borehole. Steel casing prevents borehole from collapsing as CMT well is being built. Vibration of the casing during removal reduces likelihood of bridging annular materials.	Place CMT tubing into casing with anchor plate attached to bottom of tubing. Use tubing centralizers to center tubing inside sonic casing. Add alternating lifts of sand and bentonite pellets as casing is withdrawn using either gravity placement, tremie methods or using the Solinst Mini Sand Bentonite Injector (561M).	Depths up to 300 feet. Use casing with an inside diameter (ID) of at least 4 inches (100 mm). Addition of water to casing may be needed to counteract buoyancy and heaving sand as casing is removed.
Hollow Stem Auger (HSA)	Rigs widely available. Augers provide temporary casing that can be withdrawn as CMT System is constructed.	Place CMT tubing with anchor plate into borehole inside of hollow stem augers. Add alternating lifts of bentonite pellets and sand as augers are removed. CMT tubing centralizers may be needed to keep annular space open during well construction.	Generally limited to depths of approximately 100 feet. Water may need to be added to augers to counteract heaving sand conditions. Use augers with at least a 4-inch ID.
Direct Push (DP)	Rigs are widely available.	Insert CMT tubing into DP casing, then withdraw casing.	Best for shallow installations where sand collapses around CMT tubing. May be difficult to tremie sand and bentonite due to small annular space between CMT tubing and DP casing.
Air Rotary with Casing Advance	Casing prevents borehole from collapsing as CMT well is being built gives a consistent-diameter borehole. Prevents redistribution of contaminants along borehole wall during drilling.	Place CMT tubing into casing with anchor plate. CMT tubing centralizers should be used to center tubing in borehole. Add alternating lifts of sand withdrawn, using either gravity placement, tremie methods or using the Solinst Mini Sand Bentonite Injector.	Select casing with at least a 4-inch (100 mm) ID. Addition of water is commonly needed to prevent heaving as casing is removed.
Mud Rotary	Widely available.	Place CMT tubing directly into borehole with anchor plate attached to bottom of tubing. CMT tubing centralizers should be used to center CMT tubing in borehole. Place sand pack and bentonite with a tremie tube and grout pump.	Thin drilling fluid as much as possible prior to installing annular materials. Use a coarse-grained filter pack. Mud filter cake can be difficult to remove with development methods available for CMT wells.



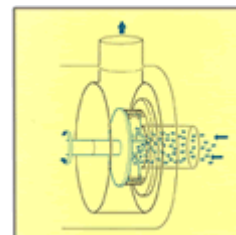
In-Line Mixers

[Corporate Info](#)[What's New](#)[Batch Mixers](#)[Lab Mixers](#)[In-Line Mixers](#)[Powder/Liquid Mixers](#)[Specialty Mixers](#)[Sales Offices](#)[Application Reports](#)[Technical Info](#)[Trade Shows](#)[Contact Us](#)[Search](#)[Home Page](#)

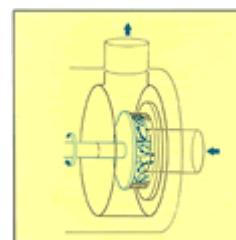
Silverson Inline Mixers -- A Closer Look

Silverson's line of high shear In-Line mixers offers a great many advantages to the processor - speed, versatility, self-pumping, aeration-free, guaranteed efficiency. At the heart of every mixer is Silverson's high performance rotor/stator workhead.

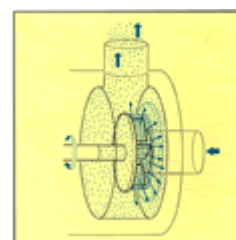
Stage 1. The high-speed rotation of the rotor blades within the precision machined mixing workhead exerts a powerful suction, drawing liquid and solid materials into the rotor/stator assembly.



Stage 2. Centrifugal force then drives the materials towards the periphery of the workhead where they are subjected to a milling action in the precision machined clearance between the ends of the rotor blades and the inner wall of the stator.



Stage 3. This is followed by intense hydraulic shear as the materials are forced, at high velocity, out through the perforations in the stator, then through the machine outlet and along the pipework. At the same time, fresh materials are continually drawn into the workhead, maintaining the mixing and pumping cycle.



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APPENDIX Iii

BIOBARRIER PILOT #2 SUBSTRATE REQUIREMENTS

Section A: Barrier Dimensions

Width of proposed barrier perpendicular to groundwater flow

30 ft

9.1 m

Minimum depth to contamination

5 ft

1.5 m

Maximum depth of contamination

20 ft

6.1 m

Barrier thickness parallel to groundwater flow

7.5 ft

2.3 m

Treatment thickness

15 ft

4.6 m

Surface area of barrier face

450 ft²42 m²**Section B: Site Hydrogeologic Data**

Total Porosity

(decimal)

Effective Porosity

0.25 (decimal)

Hydraulic Conductivity

ft/day

cm/sec

Hydraulic Gradient

0.00343 ft/ft

Seepage velocity (V_s)

0.0520 ft/day

0.0158 m/day

Groundwater flowrate through barrier (Q)

44 gal/day

166 L/day

Section C: Barrier Design Lifespan For One Application

Total groundwater volume treated over design life

10 year(s)

typical values 5 to 10 years

159,717 gallons

604,677 L

Section D: Electron Acceptors

Inputs	Typical Value	GW Conc. (mg/L)	MW (g/mole)	e ⁻ equiv./mole	Stoichiometry Contaminant/H ₂ (wt/wt H ₂)	Hydrogen Demand (g H ₂)
Dissolved Oxygen (DO)	0 to 8	0.5	32.0	4	7.94	38.0923174
Nitrate Nitrogen (NO ₃ ⁻ - N)	1 to 10		62.0	5	12.30	
Sulfate (SO ₄ ²⁻)	10 to 500	2	96.1	8	11.91	101.514795
Tetrachloroethene (PCE), C ₂ Cl ₄		124	165.8	8	20.57	3645.68538
Trichloroethene (TCE), CHCl:CCl ₂		0.5	131.4	6	21.73	13.9156555
cis-1,2-dichloroethene (c-DCE), C ₂ H ₂ Cl ₂		1	96.9	4	24.05	25.1467025
Vinyl Chloride (VC), CH ₂ =CCl ₂		0.005	62.5	2	31.00	0.0975147
Carbon tetrachloride, CCl ₄			153.8	8	19.08	
Chloroform, CHCl ₃			119.4	6	19.74	
sym-tetrachloroethane, C ₂ H ₂ Cl ₄			167.8	8	20.82	
1,1,1-Trichloroethane (TCA), CH ₃ CCl ₃		3.6	133.4	6	22.06	98.6787664
1,1-Dichloroethane (DCA), CH ₃ CHCl ₂		0.6	99.0	4	24.55	14.7806796
Chloroethane, C ₂ H ₅ Cl			64.9	2	32.18	
Perchlorate, ClO ₄ ⁻			99.4	8	12.33	
Hexavalent Chromium, Cr(VI)			52.0	3	17.20	
User added						
User added						
User added						

Section E: Additional Hydrogen Demand and Carbon Losses

Generation (Potential Amount Formed)	Typical Value	GW Conc. (mg/L)	MW (g/mole)	e ⁻ equiv./mole	Stoichiometry Contaminant/H ₂ (wt/wt H ₂)	Hydrogen Demand (g H ₂)	DOC Flux (moles)
Estimated Amount of Fe ²⁺ Formed	10 to 100	20	55.8	1	55.41	218.266353	
Estimated Amount of Manganese (Mn ²⁺) Formed		5	54.9	2	27.25	110.934913	
Estimated Amount of CH ₄ Formed	5 to 20	10	16.0	8	1.99	3039.1793	
Target Amount of DOC to Release	60 to 100	100	12.0				5034.36

Note:

Calculations assume:

- all reactions go to completion during passage through emulsified edible oil treated zone; and,
- perfect reaction stoichiometry.

Section F: Substrate Requirement Calculations Based on Hydrogen Demand and Carbon Losses

Stoichiometric Hydrogen Demand

16 pounds

DOC Released

173 pounds

Pounds Hydrogen Produced per Pound Substrate

0.18 pounds H₂/pound substrate

Soybean Oil = 0.18

Soybean Oil Emulsion Concentrate = 0.11

Substrate Density

7.7 pounds substrate/gallon

Soybean Oil = 7.7 lbs/gal

Soybean Oil Emulsion Concentrate = 7.66 lbs/gal

Substrate Requirement Based on Stoichiometric Hydrogen Demand and Carbon Losses

262 pounds

34 gallons

Section G: Substrate Requirement Calculations Based on Adsorptive Capacity of Soil

Adsorptive Capacity of Soil

0.0018 lbs oil/lbs soil

Typical Values = 0.001 to 0.004

Bulk density of soil

124 lbs/ft³

Weight of sediment to be treated

417,897 lbs

Substrate Requirement Based on Adsorptive Capacity of Soil

752 pounds

98 gallons